UNITED STATES DEPARTMENT OF AGRICULTURE
Agricultural Research Administration
Bureau of Agricultural and Industrial Chemistry

SOYBEANS: CERTAIN AGRONOMIC, PHYSICAL, CHEMICAL, ECONOMIC, AND INDUSTRIAL ASPECTS

By
J. H. Shollenberger, Commodity Development Division
Warren H. Goss, Engineering and Development Division
Northern Regional Research Laboratory
Peoria, Illinois

May 15, 1945

CONTENTS

	Page
ORIGIN AND DESCRIPTION	1
STRUCTURE	4
CHEMICAL COMPOSITION	5
Protein	6
Oil	10
Carbohydrates	15
Ash	16
Vitamins	16
CULTURE AND HARVESTING	20
PRODUCTION	23
CROP DISPOSITION	29
Relative importance as a crop	29
MARKETING	29
Grades	32
International trade	32
Prices	33
UTILIZATION OF WHOLE SOYBEANS	37
Seed	37
Feed	37
Food	39
INDUSTRIAL DEVELOPMENT	42
History of industry	42
Processing	43
Derived products	44
Production of oil and meal	44
Considerations in determining size, type, and location of plants	47
Processing costs	47
Size of plant	49
Milling-in-transit privilege	51
Other economic factors	53
Location and capacity of existing plants	54
UTILIZATION OF SOYBEAN OIL	57
Shortening	62
Margarine	67
Other edible products	67
Soap	67
Paints and varnishes	70
Linoleum and oilcloth	73
Printing inks	73
Miscellaneous products	76
New developments	77
UTILIZATION OF PROTEIN FRACTION	78
Feed	78
Food	78
Industrial	80
SELECTED REFERENCES	82

ACKNOWLEDGMENTS

The authors gratefully acknowledge the valuable assistance of R. T. Milner, A. K. Smith, J. J. Curtis, C. M. Jaeger, and W. M. Edwards, members of the staff of the Northern Regional Research Laboratory.

ORIGIN AND DESCRIPTION

The origin of the soybean is lost in antiquity. Ancient Chinese literature, however, reveals that it was extensively cultivated and highly valued as a food as far back as written records were kept. The oldest recorded evidence of soybean existence is found in a description of the plants of China written by the Chinese emperor, Sheng Nung, in 2838 B.C. Soybeans are mentioned repeatedly in later Chinese records. These records which deal with methods of culture, varieties for different purposes, and numerous uses, indicate that the soybean was perhaps one of the oldest crops grown by man. For a long time soybeans have been considered the most important legume in China and one of the five sacred grains essential to the existence of Chinese civilization.

The production of soybeans was tried in England, France, Germany, and Hungary in the seventeenth century but their culture did not become commercially established in European agriculture until within recent years.

They were first mentioned in American literature in 1804 when James Mease urged their culture in Pennsylvania. In 1889 several varieties were brought to this country from Japan by the Massachusetts Agricultural Experiment Station, but not until 1898 did the U. S. Department of Agriculture begin introducing soybeans from foreign sources for production in the United States. Prior to 1898 there had been only eight varieties of soybeans in this country. By 1907 there were 23 varieties described as known in the United States; by 1913, the number had increased to 427; and by 1925, to 1133. In all, more than 10,000 introductions have been made by the Department from China, Manchuria, Japan, Korea, Java, Sumatra, and India; representing over 2,500 distinct types.

Though introduced and grown largely at first as a forage crop, the cultivation of soybeans as a commercial seed crop soon became of primary importance. The expansion, since 1925, in soybean seed production, processing, and utilization has been one of the most phenomenal developments of American agriculture. This crop now appears firmly established, and the oil produced from soybeans has come to fill an important place in the domestic vegetable oil supply and economy.

The soybean (Soja max (L) Piper) is a summer leguminous annual. The stem is rather woody and may range from one to six feet in height but is usually 2 to 3-1/2 feet tall with five or six main branches upon which are borne the leaves and clusters of seed pods. The pods generally are 1 to 2-1/2 inches long and contain from one to four seeds which vary in size and color with the variety. The seeds, if unicolored, may be straw yellow, olive yellow, green, brown, or black, when mature. Bicolored seeds occur in some varieties, the most common combinations being green or yellow with "saddles" of black or brown, some varieties have a brindled brown and black pattern. The stems, leaves, and seed pods are covered with short, reddish brown or gray hairs.

From the large number of varieties introduced into the United States, wide differences have been encountered in size, shape, color, composition, quality of seed, length of time required to reach maturity, and adaptation to soil and climatic conditions. Selection from this large collection has resulted in more than 100 named varieties being now available for production in the United States. Others are under further test by the U. S. Department of Agriculture and several of the state agricultural experiment stations.

Soybeans are grown both for forage and seed production. Of those suited for seed, only a few are especially adapted for use as human food, by far the greater proportion of seed production being for processing into oil and meal. Yellow-seeded varieties are the type preferred for seed production, but they may also be used for forage purposes if heavier rates of seeding are used. Black- or brown-seeded varieties are generally used for forage and are for the most part smaller-seeded, finer-stemmed, and more leafy; and they contain lower percentages of oil than the yellow-seeded varieties. Generally, straw-yellow or olive-green seeded varieties are the most suitable for eating purposes either as dry or as green beans. They cook easily and have a mild and nutty flavor. As this report is chiefly concerned with the industrial utilization of soybeans, emphasis will be given therein to varieties recommended for seed production for such purposes.

In the United States the following varieties, classified according to use and length of growing season, have been recommended by the agronomy specialists,1/ of the Bureau of Plant Industry Soils, and Agricultural Engineering, U. S. Department of Agriculture for production:

<u>For industrial uses:</u>

Very early (100 days or less):
Manchukota, Mandarin, Minsoy.

Early (101 to 110 days):
Dunfield, Earlyana, Elton, Habaro,
Illini, Lincoln, Manchu, Mandell,
Mingo, Mukden, Ontario, Richland,
Seneca, Viking.

Medium early (111 to 120 days):
Chief, Harbinsoy, Mansoy, Patoka, Scioto.

1/ Soybeans: Culture and varieties. By W. J. Morse and J. L. Cartter. U. S. Department of Agriculture, Farmers' Bull. 1520, November, 1939.

Medium (121 to 130 days):
Boone, Gibson, Macoupin.

Medium late (131 to 140 days):
Arksoy, Easycook, Haberlandt, Herman, Hollybrook, Magnolia, Morse, Ogden, Ralsoy, Tokyo.

Late (141 to 160 days):
Clemson, Hayseed, Mamloxi, Mammoth Yellow, Mamredo, Missoy, Volstate, Woods Yellow.

Very late (161 or more days):
Charlee, Creole, Delnoshat.

For forage purposes:

Very early (100 days or less):
Cayuga, Ogemaw, Soysota, Wisconsin Black.

Early (101 to 110 days):
A.K., Black Eyebrow.

Medium early (111 to 120 days):
Harbinsoy, Ilsoy.

Medium (121 to 130 days):
Ebony, Kingwa, Norredo, Peking, Virginia, Wilson, Wilson-Five.

Medium late (131 to 140 days):
Laredo, Mammoth Brown, Tarheel Black.

Late (141 to 160 days):
Clemson, Hayseed, Missoy.

Very late (161 or more days):
Avoyelles, Biloxi, Charlee, Creole, Georgian, Monetta, Otootan, Palmetto, Yelredo.

For food purposes:

Very early (100 days or less):
Green vegetable - Agate, Sioux, Giant Green Hidatsa, Sac. Dry edible - Giant Green Hidatsa, Sac.

Early (101 to 110 days):
Green vegetable - Bansei, Chusei, Etum
Kanro, Kanum
Dry edible - Bansei, Chusei, Goku, Kanro,
Kanum.

Medium early (111 to 120 days):
Green vegetable - Emperor, Hakote, Hokkaido,
Jogun, Kura, Sousei, Willomi, Wolverine.
Dry edible - Emperor, Hokkaido, Jogun, Sousei,
Willomi, Wolverine.

Medium (121 to 130 days):
Green vegetable - Funk Delicious, Hahto,
Imperial.
Dry edible - Funk Delicious, Hahto, Imperial.

Medium late (131 to 140 days):
Green vegetable - Aoda, Higan, Rokusun
Dry edible - Easycook, Higun, Rokusun
Tokyo.

Late (141 to 160 days):
Green vegetable - Delsoy, Jackson, Jefferson,
Nanda
Dry edible - Delsoy, Jefferson, Nanda.

Very late (161 or more days):
Green vegetable - Cherokee, Seminole
Dry edible - Seminole

STRUCTURE

The soybean seed is made up of the seed coat and the embryo. The seed coat or hull is that part of the seed which encloses the embryo and is relatively thick and hard. The embryo consists of the seed leaves (cotyledons), the root (radicle), the shoot (plumule), and the part of the embryo (hypocotyl) between the attachment of the cotyledons and the upper end of the rudimentary root. The seed has little or no endosperm; the latter being absorbed by the developing embryo before the seed is fully developed.

The average soybean seed consists of approximately 8 percent seed coat and 92 percent embryo, the latter being 97.8 percent cotyledons and 2.2 percent other embryonic organs. Table 1 shows the proportion and composition of the various parts of the soybean seed.

Table 1. - Proportion and composition of the component parts of soybean seed

Component part	Proportion of seed	Moisture	Protein (Nx6.25)	Carbo-hydrates	Fat	Ash
	Percent	Percent	Percent	Percent	Percent	Percent
Seed coat	8	12.53	7.00	21.02	0.60	3.83
Embryo:	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Cotyledons	90	10.57	41.33	14.60	20.75	4.38
Other organs	2	12.01	36.93	17.32	10.45	4.08

Source: Data from "The composition and characteristics of soybeans, soybean flour, and soybean bread" by L. H. Bailey, et al. Cereal Chem. Vol. 12, No. 5. Sept. 1935.

Soybean seeds range in weight from 0.75 gm. per 100 seeds for certain small-seeded wild types to 35.0 gm. per 100 seeds for certain large-seeded edible types. Common commercial types for industrial use average from about 13.0 to 16.0 gm. per 100 seeds. Among the later, industry has no particular preference for either the large- or small-seeded varieties. Farmers, however, prefer smaller seeded varieties because they emerge through a crusted soil surface with less difficulty and because the larger number of seeds per bushel permits a lower seeding rate.

In shape, soybeans may be flat, oval, or round, according to variety. Shape, however, is not important in its effect upon industrial processing or other uses.

CHEMICAL COMPOSITION

From the standpoint of industrial processing, the principal interest in the composition of soybean seed is in the content and quality characteristics of its protein and oil constituents.

There are voluminous data in the literature concerning the chemical composition of soybeans and also of the effect of variety, environment, soil fertility, etc., on the characteristics and relative proportions of their various chemical constituents, but only enough of these data will be summarized and presented in this report to give a general picture.

The chemical composition of soybean seed as influenced by variety, environment, and soil fertility level was given detailed analysis by Cartter and Hopper.2/ Summarily, they found that varieties and strains of soybeans inherit qualitative and quantitative composition tendencies, but that environment and soil fertility level also have an important influence thereon. As regards specific constituents or characteristics they report as follows:

In general, the oil content of the soybean seed is most specifically a varietal characteristic, and the iodine number of the oil is about equally influenced by variety and climate under the conditions observed in their investigations. The percentages of oil and total sugars usually vary in the same direction and inversely with the percentages of protein. No large variations were observed in the percentages of crude fiber in the seed and unsaponifiable matter in the oil, but there was observed some variation in these constituents due to variation in seed size and ratio of seed coat to cotyledon. Temperature levels significantly influenced the calcium content of the seed produced by a given variety. Invariably, high calcium content resulted when the soybeans were grown at high temperatures. Total ash, phosphorous, and potassium content of the seed appeared to be influenced more by soil type and fertility than by variety or variations in climate.

Data summarized in table 2 show the chemical composition of 10 varieties and strains of soybeans, studied by Cartter and Hopper, and the range in content of various constituents of soybeans grown at five locations during the five-year period, 1936-40.

Table 3 contains results of hundreds of analyses by the U. S. Department of Agriculture, reported by L. H. Bailey et al, on the chemical compositions of many varieties of soybeans grown under divers environments.

Protein

Protein makes up a larger percentage of the soybean than any other of its constituents. Moreover, it has many uses; as human food, livestock feed, and as an industrial raw material. Soybean protein also contains many of the biologically essential amino acids which contribute to its value both in human nutrition and as a protein concentrate in feeding livestock.

2/ Cartter, J. L. and Hopper, T. H. Influence of variety, environment, and fertility level on the chemical composition of soybean seed. U. S. Dept. Agr. Tech. Bul. 787 (1942)

The commonest form in which soybean protein is available on the market is oil meal, but it is also the main constituent of soy flour and other edible soybean products, and it is marketed in a purified form for various industrial uses.

Wide variations in the protein content of soybeans occur as the result of differences in variety, environment, and soil fertility, and the protein content of soybean oil meal is directly related to the protein content of the soybeans used in processing. However, because the great bulk of the soybeans processed for oil in this country consists of only a few varieties grown principally in a relatively small area, the processor normally finds that the oil meal he produces does not vary a great deal in protein content from one lot of beans to another.

Table 2. - The average percentage of protein, oil, total sugar, crude fiber, and total ash, and iodine number of seed of 10 varieties and strains of soybeans grown at five locations[1] during the five-year period 1936-40

Variety or strain	Moisture-free basis					Iodine number
	Protein (N. x 6.25)	Oil	Total sugar 2/	Crude fiber 3/	Total ash	
	Percent	Percent	Percent	Percent	Percent	Percent
Mandarin	46.42	18.16	6.76	5.39	5.37	127.6
Mukden	45.76	19.26	6.83	5.33	5.00	124.6
Dunfield, A	41.38	20.97	8.24	5.34	4.65	124.9
Dunfield, B	41.42	20.91	8.40	5.45	4.61	124.4
Illini	42.59	19.99	8.83	5.26	4.31	130.5
Manchu	44.06	19.40	7.78	5.42	5.12	130.2
Scioto	42.47	20.29	8.22	5.23	5.17	133.0
T-117	41.86	20.37	8.61	5.51	5.02	123.9
Peking	40.58	17.07	7.50	6.48	5.21	137.7
Boone	42.18	19.91	8.58	5.80	4.97	129.8

1/ - Grown at Ames, Iowa; Columbia, Missouri; Urbana, Illinois; LaFayette, Indiana; and Columbus, Ohio.

2/ - Calculated as sucrose.

3/ - Average of only 4 years, 1936-39.

Source: Influence of variety, environment, and fertility level on the chemical composition of soybean seed. By J. L. Cartter and T. H. Hopper. U. S. Dept. Agr. Tech. Bul. 787. May 1942.

Table 3. - Minimum, maximum, and average chemical composition of soybeans

Constituent	Minimum	Maximum	Average
	Percent	Percent	Percent
Moisture	5.02	9.42	8.0
Ash	3.30	6.35	4.6
Fat	13.50	24.20	18.0
Fiber	2.84	6.27	3.5
Protein (N x 6.25)	29.60	50.30	40.0
Pentosans	3.77	5.45	4.4
Sugars	5.65	9.46	7.0
Starch-like substances by diastase	4.65	8.97	5.6
P_2O_5	1.50	2.18	1.7
K_2O	2.01	2.64	2.3
CaO	.49	.63	.5
MgO	.46	.55	.5

These data include many varieties grown under divers environments.

Source: Soybeans, soybean flour, and soybean bread. By L. H. Bailey, et al. Cereal Chem. Vol. 12, No. 5. Sept. 1935.

Oil

The oil content (moisture-free basis) of soybeans may range from approximately 13.5 to 24 percent of the total weight of the seed. Leading commercial varieties usually contain from about 18 to 21 percent oil. Nearly 99 percent of the oil is found in the cotyledons; the remainder is in other parts of the embryo and the seed coat (see table 1). Soybean oil consists of the glycerides of saturated and unsaturated fatty acids and a number of ether lipid materials. These latter include the phosphatides, sterols, long chain hydrocarbons, alcohols, ketones, free fatty acids, pigments, vitamins, antioxidants, and small amounts of nonlipid gummy or mucilaginous substances. The approximate fatty acid composition, corresponding to an iodine value of 130, is: 14.6 percent saturated, 25.3 percent oleic, 55.0 percent linoleic, and 5.1 percent linolenic acids. Table 4 shows the fatty acid composition of various soybean oils. The type and amount of the various lipids which may be present in the oil are influenced both by the variety of seed and the environment during growth.

Because of the many factors which may affect the occurrence of and composition of oil within the soybean, it is not surprising that considerable variation is met with in the oil content of soybeans and in the characteristics of the oil. However, although the oil from a particular lot of soybeans may differ considerably in quantity and quality from another, commercial soybean oils are much more uniform owing to the practice of mixing of different lots of seed, or of different batches of oil during processing. Also the numerous refining operations tend to eliminate much of the secondary materials, especially gums, phosphatides, free fatty acids, unsaponifiable matter, and pigments.

There are many evaluations of certain physical and chemical characteristics or properties which may be applied to soybean oil in order to determine its quality, freedom from associated impurities or added adulterants, adaptability to various processes or uses, and for other purposes. Some of these tests are important only for highly specialized applications or processes, whereas others apply to properties which must always be known and so have been made the basis of trading rules for buying and selling soybean oil. Most crude soybean oil is bought and sold in accordance with trading rules established by the National Soybean Processors Association, an organization representing the largest part of the soybean crushing industry. There are two sets of these rules, one applying to crude oil for edible purposes and one to crude soybean oil for technical uses.

Crude soybean oil for edible purposes:

The trading rules applying to crude soybean oil for edible use have recently been modified considerably, and because of war-time developments

Table 4. - Composition of solvent-extracted soybean oil

Source	Variety	Oil: Iodine number	Oil: Thiocyanogen number	Oil: Unsaponifiable matter	Fatty acids 1/: Unsaturated	Fatty acids 1/: Saturated 2/	Fatty acids 1/: Oleic- 18 carbon atoms 1 double bond	Fatty acids 1/: Linoleic- 18 carbon atoms 2 double bonds	Fatty acids 1/: Linolenic- 18 carbon atoms 3 double bonds
				Percent	Percent	Percent	Percent	Percent	Percent
Manchuria	Unknown	137.0	80.5	1.2	84.7	3/ 15.3	21.3	55.2	8.2
Manchuria 4/	Unknown	132.2	78.3	.6	84.2	3/ 15.8	25.9	51.2	7.1
United States	Unknown	130.5	80.4	.65	84.9	3/ 15.1	24.7	53.7	6.5
United States	Mammoth	134.2	81.9	.57	85.2	3/ 14.8	24.7	50.5	10.0
Manchuria	Unknown	133.8	79.7	.54	88.2	11.8	25.9	58.8	3.8
United States	Dunfield	6/ 102.9	78.0	.84	88.0	5/ 12.0	60.0	25.0	2.9
United States	Dunfield	127.3	80.2	.70	86.8	5/ 13.2	34.0	49.1	3.6
United States	Dunfield	124.0	79.6	.66	86.9	5/ 13.1	34.8	46.0	6.0
United States	Illini	131.6	81.3	.34	88.0	5/ 12.7	27.7	53.7	5.9
United States	Peking	137.8	84.5	.93	87.6	5/ 12.4	24.4	56.2	7.3
United States	Seneca	139.4	85.1	.61	88.1	5/ 11.9	24.7	55.4	8.0
United States	Wild beans	151.4	87.4	2.20	86.5	5/ 13.5	11.5	63.1	12.1

1/ - Calculated on the basis of total fatty acids as 100 percent and not as glycerides.

2/ - The saturated acids are approximately 2/3 palmitic, which has 16 carbon atoms, and 1/3 stearic, which has 18 carbon atoms. Arachidic and lignouric acids, containing respectively 20 and 24 carbon atoms, are present in very small amounts.

3/ - Bertrame oxidation method.

4/ - Refined oil.

5/ - Twitchell's lead salt alcohol method. This method yields results which are 1.5 to 2.0 lower in percentage than the Bertrame oxidation method which latter is generally considered the more accurate.

6/ - Abnormal oil.

Source: Taken from a table in Soybean Chemistry and Technology. By Klare S. Markley and Warren H. Goss. The Chemical Publishing Company, Brooklyn, New York. 1944.

in the food supply situation, they are quite subject to change. In their present form, they provide discounts and premiums based on the amount of green color in the crude oil, the bleach color of the oil when refined, and amount of sludge which settles to the bottom of the tank car in transit. At times, discounts have been applied on the basis of refining loss.

Refining loss is the percentage of oil not recoverable as such from a laboratory refining of the crude oil, carried out in a rigidly specified manner approximately assimilating plant practice. It is indicative of the amount of material that the refiner must discard as lower-priced soap stock and bears a rough relation to the content of free acids, phosphatides, and similar materials in the oil. At present, refining loss is not a discount factor in soybean oil marketing, but attempts are being made to adopt trading rules which provide for premiums or discounts for high or low refining loss at the rate of three-fourths percent of the purchase price for each one percent of loss, the basis being some value yet to be agreed upon in the neighborhood of 6 percent.

Green color of the crude oil is an important factor in the grading of oils obtained from so-called green-damaged soybeans, in which exceptional climatic or other conditions have arrested development of the seeds prior to their attaining full maturity. These oils are often a brilliant green instead of yellow, and the removal of the green color involves an unusually drastic bleaching treatment, with consequent additional expense to the refiner. The degree of green coloration is determined by matching the oil against specified solutions of nickel sulfate, and discounts are applied in accordance with whichever of three grades, Nos. 1, 2, and 3, into which the oil is classified.

The importance of color in a finished product, in edible oil technology, arises from the necessity for producing nearly snow-white shortenings and similar products in order to meet consumer preference. Besides the green color in the oil, caused by arrested maturity of the soybeans, another type of color is taken into account by the trading rules, namely, the Lovibond red color after application of standard laboratory refining and bleaching tests. A high red refined bleach color is difficult, and sometimes impossible, to remove without resorting to drastic bleaching treatments which are expensive and which often impair the keeping quality of the oil. Indeed, a high red color in refined, and bleached oil is vastly more deleterious to the quality of the finished products than is the green color imparted to crude oils because of frost damage. There are many causes of red color in refined and bleached oil, but the most important is so-called "field damage" to the soybeans from which the oil is obtained. Field damage occurs when the beans are not harvested promptly after reaching maturity and is the result of bacterial and other forms of decomposition while the beans are exposed to extended periods of wet weather. Similar damage is often caused by improper soybean storage conditions. At the present time, discounts are specified in the oil trading rules for various degrees of red color in refined and bleached soybean oil which is destined for consumption in edible products.

When a tank car of crude soybean oil arrives at the refinery, there is ordinarily a deposit of sludge in the bottom. This is caused by the precipitation of phosphatides and other impurities, along with a certain amount of oil which is physically entrained. In many soybean mills, various treatments are employed for removing sludge-forming contaminants before the oil is shipped, for a penalty is assessed by the buyer for sludge content of greater than 150 pounds per tank car.

Crude soybean oil for technical purposes:

Prior to approximately 1930, most soybean oil was used in paints, varnishes, and similar industrial products. Standard specifications for the oil were consequently applied, based upon characteristics which are important to the paint and varnish industry. With the subsequent shift of soybean oil consumption into food channels, these specifications have become less important, except in special cases in which it is stipulated that the oil is destined for technical uses. The National Soybean Processors' Association present standards are outlined in Table 5.

Iodine number, as a measure of the degree of unsaturation of soybean oil, is of especial importance in evaluating oil for various uses. The percentages of linoleic and linolenic acids in the oil increase with increasing iodine number. As these are the film-forming constituents of the oil, soybean oil of a maximum iodine number is preferred by the drying oil trade for use in paints and varnishes. The edible oil trade prefers soybean oil of a minimum iodine number because it requires less hydrogen in the hardening process and because the final product has better keeping properties. Examination at the U. S. Regional Soybean Industrial Products Laboratory* of hundreds of samples of commercial and laboratory-processed oils, including crude, semi-refined, and completely refined oils derived from many varieties of soybeans grown under a wide range of soil and climatic conditions, revealed iodine numbers ranging from 103 to 151. Most of the commercial soybean oils were found to have iodine numbers ranging from 127 to 133. Crude oils and the corresponding refined soybean oils differ only slightly in their respective iodine numbers.

The unsaponifiable matter in soybean oil includes the sterols, some phytosterolines, hydrocarbons, alcohols, and ketones. The average content

---

* By act of Congress the chemical and engineering investigations of this Laboratory were transferred to the Northern Regional Research Laboratory on July 1, 1942.

Table 5. - Specifications for buying and selling soybean oil for technical uses 1/

Characteristic	Maximum	Minimum
	Percent	
Iodine number 2/ (Wijs)		130
Unsaponifiable matter	1.5	
Free fatty acids 3/	1.5	
Moisture and volatile matter at 105° C. (allowance if over 0.2%) 4/	.3	
Break or foots (Modified Gardner Method) 5/	.6	

1/ Set forth by National Soybean Processors Association, 1944-5.

2/ This specification applies only to high iodine value grade oil when stated in the original contract.

3/ Penalty of 1/2 percent of purchase price for each 1/2 percent or fraction thereof in excess of 1.5 percent.

4/ Penalty of 2/10 percent of purchase price for each 1/10 percent or fraction thereof in excess of 2/10 percent.

5/ Penalty of 2/10 percent of purchase price for each 1/10 percent or fraction thereof in excess of 0.6 percent.

of unsaponifiable matter found in 153 samples of soybean oils examined at the U. S. Regional Soybean Industrial Products Laboratory was found to be 0.75 percent with individual variations ranging from 0.52 to 1.61 percent.

Free fatty acids are contained in varying amounts in soybean oils. Technically, free fatty acid content of soybean oil is expressed in terms of acid number. Examination of a large number of freshly produced soybean oils has shown variations in acid number as follows: Solvent-extracted oils 0.35 to 3.85; expeller-pressed oils 0.86 to 2.10. Alkali refining results in a reduction of the free fatty acid content, and carefully refined and deodorized soybean oil should have an acid number of 0.10 or less. The acid number of soybean oil may become relatively large, however, under adverse storage conditions which cause hydrolysis or splitting of the glycerides. The trade expresses the content of free fatty acids in an oil on a percentage basis, which in the case of soybean oil is calculated as oleic acid.

The "break" material or foots, found in most crude soybean oils, consists principally of phosphatides, pigments, and mucilaginous materials which are removed from the seeds along with the oil. The method used in pressing the soybeans and in extracting the oil and the method and degree of clarification employed affect the quantity of extraneous materials which remain in the crude oil. When the oil goes directly into the edible or drying oil industry, excessive "break" material is objectionable because it leads to increased refining losses.

The amount of "break" material usually obtained by the Gardner acid-heat-break method varies from 0.04 to 0.20 percent for extracted oils and from 0.20 to 1.00 percent for expeller oils. A correlation exists between the amount of "break" material found by the "heat-break" method and the loss sustained in refining with respect to many soybean oils, but numerous exceptions occur especially in the case of solvent-extracted oils.

Carbohydrates

The carbohydrates contained in soybeans are of less importance, from the standpoint of uses, than the protein and the oil. In addition, relatively little is known about the percentage of carbohydrates present in the soybean and their characteristics. This is probably due to the fact that soybeans contain a relatively small amount of carbohydrates and that these are associated in their natural state with so many impurities that isolation and identification are difficult.

Carbohydrate substances are present in the soybean in many different forms including celluloses, free sugars, pentosans, hexosans, and probably other forms. There is disagreement concerning the presence of starch in soybeans; some investigators report its presence in amounts up to 3 percent whereas others report inability to demonstrate its presence.

Table 2 (page 8) contains data showing the total sugar content, calculated as sucrose, and of the crude fiber content of various soybean varieties. Cartter and Hopper found that the percentages of sugar increase and decrease with the percentages of oil and that when total sugar and oil contents change in one direction, the protein content changes in the other.

The crude fiber, a mixture of cellulosic substances and lignin, is found principally in the seedcoat of the soybean. The analysis of two samples of soybean seedcoats by Cartter and Hopper (2) showed a crude fiber content of 31.37 and 28.10 percent (dry basis), respectively.

Ash

The importance of the total ash content of soybeans depends on the use to be made of the oil meal after the extraction of the oil. If the meal is to be used for feed, a high ash content is desired; if the meal is to go into industrial channels, the mineral content is of less importance. Soybean varieties with low-ash content and high oil and protein contents are, therefore, preferred for industrial applications and at the same time they remove less minerals from the soil, per unit of raw material produced. Soybeans normally contain from 4 to 6 percent of ash. Their calcium and phosphorous contents are higher than any of the cereal grains, and few foods excel soybeans as a source of biologically available iron. Table 6 includes data showing the average total ash, phosphorous, potassium, and calcium content of 10 varieties and strains of soybeans. Table 7 presents further data regarding the mineral content of soybeans.

Vitamins

Knowledge concerning the vitamin content of soybeans and their products is important from the standpoint of their edible uses, both as human food and as feed for livestock. Since the bulk of soybean oil is consumed in food products and approximately 95 percent of soybean oil meal is used as a protein concentrate in livestock feeding, information regarding the vitamin content of soybeans and their products is essential. For non-food industrial uses, the vitamin content of the soybean is, of course, of no importance.

Reports in the literature regarding the vitamins present and the extent of their presence in soybeans and soybean products do not all completely agree. Some of these variances are undoubtedly due to varietal differences and some to lack of uniformity in the techniques employed in determining vitamin content. Furthermore, in the case of the soybean products, vitamin content is probably affected somewhat by differences in processing treatments used.

Table 6. - The average total ash, phosphorus, potassium, and calcium contents of 10 varieties and strains of soybeans grown at five locations 1/ during the 5-year period, 1936-40.

Variety or strain	Moisture-free basis			
	Total ash	Phosphorus	Potassium	Calcium
	Percent	Percent	Percent	Percent
Mandarin	5.37	.696	1.64	.386
Mukden	5.00	.660	1.74	.240
Dunfield, A	4.65	.626	1.62	.226
Dunfield, B	4.61	.627	1.58	.221
Illini	4.31	.623	1.67	.252
Manchu	5.12	.670	1.67	.313
Scioto	5.17	.658	1.68	.343
T-117	5.02	.654	1.67	.248
Peking	5.21	.727	1.75	.272
Boone	4.97	.653	1.71	.253

1/ Grown at Ames, Iowa; Columbia, Missouri; Urbana, Illinois; LaFayette, Indiana; and Columbus, Ohio.

Source: Influence of variety, environment, and fertility level on the chemical composition of soybean seed. By J. L. Cartter and T. H. Hopper. U. S. Dept. Agr. Tech. Bul. 787, May 1942.

Table 7.- Mineral content of soybeans (moisture-free basis)

Mineral	No. of analyses	Range		Mean
		Maximum	Minimum	
		Percent	Percent	Percent
Ash 1/	?	6.35	3.30	4.60
Potassium	29	2.39	0.81	1.83
Calcium	9	.30	.19	.24
Magnesium	7	.34	.24	.31
Phosphorus	37	1.08	.50	.78
Sulfur	6	.45	.10	.24
Chlorine	2	.04	.03	.03
Sodium	6	.61	.14	.24
Boron	5	.0029	.0006	.0019
Manganese	11	.0041	.0021	.0028
Iron	13	.0133	.0057	.0080
Copper	1			.0012
Barium	?	-	-	.0008
Zinc	1			.0018

Source: The mineral composition of crops with particular reference to the soils in which they were grown, a review and compilation. By Kenneth C. Beeson. U. S. Dept. Agr. Misc. Pub. 369, March 1941.

1/ Data from Table 3.

From a determination 3/ of the carotene content of over 40 different varieties of green and mature soybeans, it was found that most varieties in the green stage were very good sources of carotene, having a range of from 212 to 705 micrograms per 100-gram fresh sample, whereas the carotene content of the mature soybeans ranged from 18 to 243 micrograms per 100-gram air-dry sample. Later correlations 4/ of the carotene content with biological assays for five varieties of mature soybean seed demonstrated that the biologically active carotenoid pigment contained in the purified extract was 80 to 88.8 percent β-carotene and 2.5 to 11.8 percent α-carotene. Cryptoxanthin was not found in any of the soybeans analyzed. It was concluded that many varieties of soybeans at maturity have a carotene content as great as that of yellow corn. In terms of total vitamin A activity, however, yellow corn was superior to all varieties of soybeans studied because of the presence of relatively large amounts of cryptoxanthin in the corn.

According to most assays which have been reported, soybean oil, like most vegetable oils, contains but little vitamin A. However, the extent of this vitamin's presence in soybean oil has not been satisfactorily settled. Assays of expeller soybean flour (8% oil) and solvent-extracted soybean flour (3% oil) 5/ have indicated the presence of 36 and 30 international units of vitamin A per 100 grams, respectively.

Soybeans are a very good source of vitamin B_1 (thiamin). They also contain, in smaller amount, Vitamin B_2 or G (riboflavin). An examination 6/ of 15 samples, representing 9 varieties of soybeans, indicated that their vitamin B_1 content varied from 320 to 480 international units per 100 grams of mature soybeans. A solvent-extracted soybean oil meal assayed 280, and a hydraulic process oil meal assayed 100 international units of vitamin B_1 per 100 grams of material. 5/ Soybeans do not contain sufficient quantities of riboflavin and pantothenic acid, another component of the B-complex, to be considered a good source of these vitamins.

3/ Sherman, W. C. and Salmon, W. D. Carotene content of different varieties of green and mature soybeans and cowpeas. Food Res. 4:371-380 (1939).

4/ Sherman, W. C. Chromatographic identification and biological evaluation of carotene from mature soybeans. Food Res. 5: 13-22 (1940).

5/ Hayward, J. W. The nutritive value of soybean oil meal prepared by different methods of extraction. Oil and Soap 14: 317-321 (1937).

6/ Halverson, J. O. and Sherwood, F. W. The vitamin A activity and the vitamin B_1 content of soybeans and cowpeas. Jour. Agr. Res. 60: 141-144 (1940).

The vitamin C (ascorbic acid) content of mature soybeans is very small; however, soybean sprouts are an excellent source of this vitamin. Soybeans are also relatively poor or completely lacking in vitamin D. Reports in the literature indicate that soybean oil contains vitamin E, but to a much less marked degree than does wheat germ oil. Soybeans contain vitamin K in significant quantities. It is present in abundance in soybean oil, but no specific assay of soybean oil meal for the vitamin has been reported. Soybean seeds dried in vacuum desiccators at room temperature were found to contain 25 units of vitamin K per gram of dry material.

The soybean content of niacin, the anti-pellagra vitamin, is about the same as that of wheat and, therefore, it cannot be considered an especially important source of this vitamin.

In table 8 are presented data showing the vitamin content of midwest milling varieties of soybeans, expeller and extracted soybean oil meal, and three types of soy flour. This analysis does not include all the vitamins discussed in the preceding paragraphs, but it includes biotin and choline, the importance of which is still uncertain.

CULTURE AND HARVESTING

When properly inoculated with symbiotic bacteria, soybeans develop abundant nodules or tubercles on the roots which extract nitrogen from the soil air for plant growth. They are, therefore, considered a soil-building crop when plowed under as green manure. They also bring about some improvement in the soil when grown for seed or forage in rotation with other crops if the straw is plowed under or returned to the soil as manure.

Soybeans are especially valuable in short crop rotations with corn and small grains. However, they are used to replace oats, corn, cowpeas, or other spring sown crops. In the corn belt a rotation of corn, soybeans, wheat, and clover is quite common. In this area, the soybean crop should not be considered as a grain crop competing with corn but as a substitute for oats or barley.

The growing of soybeans, as one of the major rotation crops, is confined largely to those areas (see figure 1) where oats were formerly grown as a cash grain. This replacement of oats by soybeans is in part due to the fact that in recent years oats have experienced a weak market demand as a result of the replacement of horses by motor power, but to the extent that farmers can use oats in livestock production the crop will continue to occupy an important place in farming.

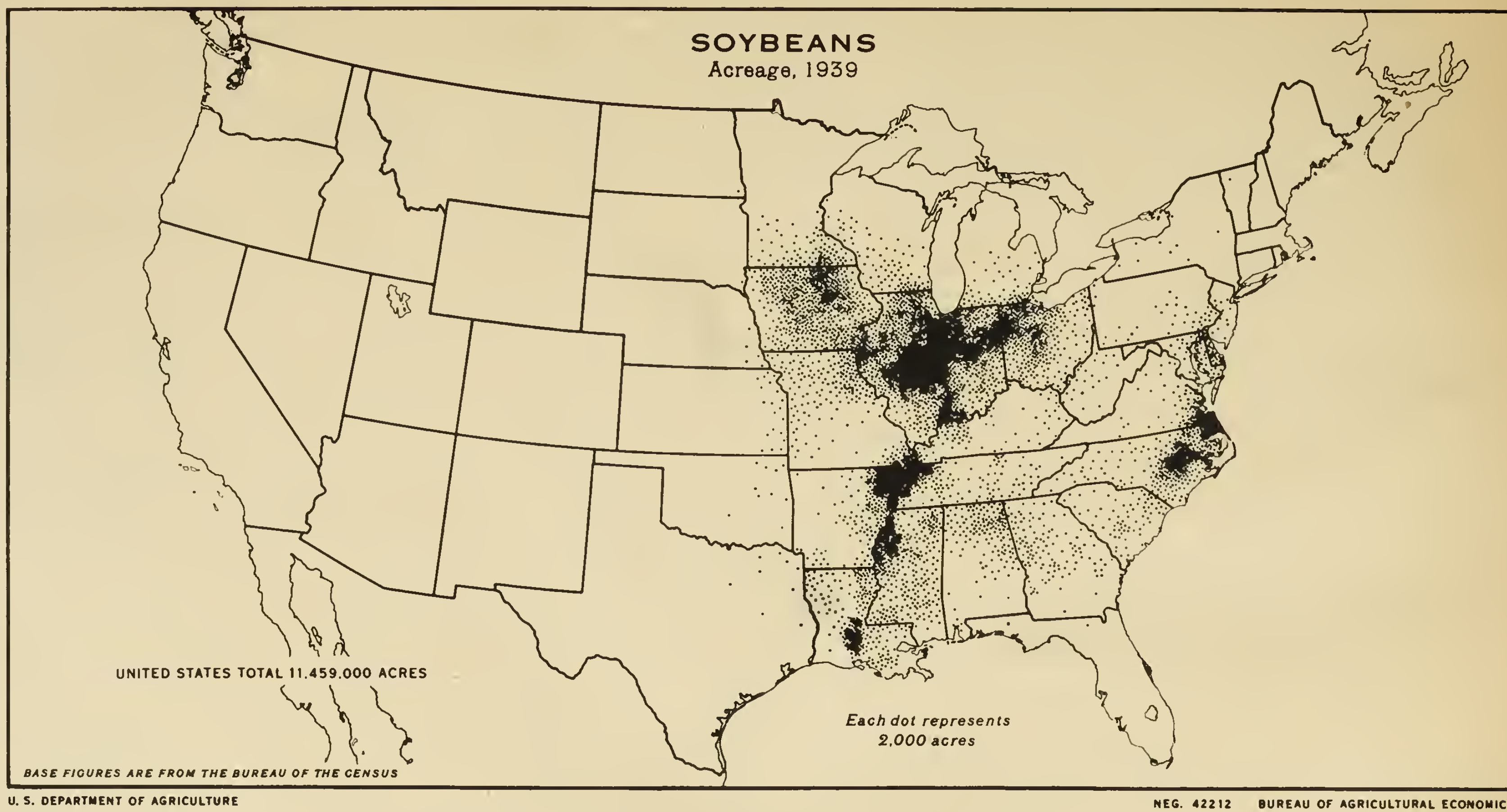

Figure 1. - Soybean acreage for all purposes.

Table 8. - Vitamin content of soybeans, soybean oil meal, and soy flour

Type of material	Vitamin A (as carotene)	Thiamin	Riboflavin	Phosphatides, as choline	Niacin	Biotin	Pantothenic acid
	I. U./100 g.	I. U./100 g.	Mcgs./100 g.	Mgs./100 g.	Mcgs./g.	Mcgs./100 g.	Mcgs./g.
Soybeans, midwest milling varieties1/	140	200 - 400	300 - 500	225	49	60	6 - 14
Expeller process soybean oil meal, 41 and 43 percent protein content1/	90 - 115	0 - 70	300 - 500	225	57	70	8 - 20
Solvent extraction process soybean oil meal, 44 percent protein content	70 - 80	70 - 200	300 - 500	225	60	73	8 - 20
High fat soy flour2/	143	170	350	220	38	57	13
Medium fat soy flour (probably expeller)2/	105	200	400	220	42	66	15
Low fat soy flour (extracted)2/	44	240	440	220	53	66	13

Sources: 1/ Soybean Products as a Feed for Livestock and Poultry. By J. W. Hayward, Part I. Feedstuffs Vol. 14, No. 49, pp. 14-17, Dec. 5, 1942.

2/ Tentative average vitamin content of soya flours, Soya Food Research Council, 3818 Board of Trade Building, Chicago 4, Illinois. Values converted from pound basis.

In certain areas the prevalence of insects or plant diseases that affect small grains, but not soybeans, may make it advisable to grow soybeans in the rotation to replace at least a part of the small grain acreage.

Soybean varieties differ in time of maturity and in adaption to soil fertility levels and soil acidity. They are sensitive in their reactions to changes of soil and climate and, generally, a variety must become acclimated to a new environment before normal yields may be expected. The period of germination is the most critical stage in their withstanding of adverse growing conditions. After soybeans are well started, however, a wet season does not seriously retard growth, and they can withstand short periods of drouth. Soybeans are less susceptible to frost than are corn, cow-peas, and field beans, and a little frost has but little adverse effect on the plants either when young or when nearly mature. They are not so sensitive to acid soils as are red clover, alfalfa, and many other crops.

Preparation of the seedbed for soybean production is generally the same as for corn, and, like corn, soybeans respond to any extra preparation of the soil.

Various successful methods of seeding soybeans are employed in different regions where large acreages are devoted to this crop. Soybeans are sown either in rows sufficiently wide to allow cultivation or in close drills. Broadcasting the seed and covering with a harrow is seldom practiced and is not advisable. The method of seeding will be determined largely by convenience and economy of cultivation and harvesting, rate of seeding, variety used, type of soil, climatic conditions, and the purpose for which the crop is grown.

For seed production, under nearly all conditions the crops should be grown in rows and given sufficient cultivation to keep down the weeds. The distance between rows may vary from 24 to 36 inches on fertile soils to 36 to 42 inches on medium fertile and poor soils. Where the combine is to be used in harvesting, some objection has been found to soybeans grown in rows because of the tendency to ridge the land during cultivation.

The rate of seeding soybeans is influenced by several factors, the most important being the purpose for which the crop is grown, size of the seed, method of planting, and environmental considerations. Generally, the quantity of seed required per acre for cultivated rows ranges from 10 to 75 pounds; for close drilling or broadcast sowing, two to two and one-half times these amounts are usually recommended. In Illinois, on good land, standard varieties such as Dunfield, Illini, and Manchu are usually seeded at the rate of about one bushel an acre in row plantings and two bushels in drilled plantings.

Improvements in methods of harvesting the soybean seed have contributed to the phenomenal increase of soybean production. Today soybeans may be harvested as efficiently and economically as any of the small grains.

The most extensively used means of harvesting soybean seeds is the combine. The advantages of this machine, which is the same type as that used for harvesting wheat and other small grains, are: loss of beans during harvesting is small, the time consumed in harvesting is minimized, and the straw is deposited back on the land where it grew. Other harvesting machines which are used include, (a) the grain binder, with the bundles being shocked and handled much the same as are wheat and oats: (b) the mower, with the crop being raked and placed in small cocks to be threshed when sufficiently dry; and (c) special soybean harvesters which gather the beans from the standing stalks.

When either the binder or mower methods of harvesting are used, the crop is cut when the seeds are in the hard dough stage, at that time the leaves of most varieties turn yellow and fall, leaving the stems bare with their clusters of seed pods. When the combine or special soybean harvester is used, the crop is permitted to cure thoroughly in the field, preferably to at least as low as 14 percent moisture. Excessive moisture, as with grain, results in spoilage in the bin.

PRODUCTION

The Orient is the principal soybean producing region of the world; and until about 1933 China, Manchuria, Chosen, and Japan, in the order named, were the foremost important soybean producing countries. These four countries produced approximately 95 percent of the total world production during the 1930-34 five-year period. During the same period, United States production accounted for only approximately 3.6 percent of the total. Since 1935, however, soybean production in the United States has increased sharply while production in the rest of the world has remained practically unchanged. This increase raised this country's soybean production to 19 percent of the world's total in 1939 (the last year for which complete world figures are available). Moreover, the United States production of 193 million bushels of soybeans in 1944, which was more than double that of 1939, undoubtedly elevated it to at least second place in actual production (next to China) and probably accounted for as much as 35 percent of the total world production. World soybean acreage and production data are presented in table 9.

United States acreage, yield, and production data for soybeans, from 1924 to 1944 are contained in table 10. Total acreage increased from 1.8 million acres in 1924 to 16 million acres in 1943 and production increased from 4.9 million bushels to almost 200 million bushels. During the same period the percentage of the crop harvested for beans increased

Table 9. - Soybean acreage and production for beans in specified countries, average 1930-34, and 1935-39 and annual 1940-43

Country	Average 1930-34	Average 1935-39	1940	1941	1942 1/	1943
	1,000 acres	1,000 acres	1,000 acres	1,000 acres	1,000 acres	1,000 acres
ACREAGE						
China	2/ 13,062	2/ 12,188	...	...	...	...
Manchuria	9,595	8,992	...	...	...	...
United States 4/	1,163	3,042	4,786	5,881	10,008	10,820
Canada	...	2/ 10	11	11	44	36
Chosen	1,958	2/ 1,921	...	...	...	...
Japan	840	2/ 812	...	...	...	...
Taiwan	20	2/ 17	...	...	...	...
Netherlands Indies	589	889	1,033	...	...	...
Rumania	2/ 4	161	3/ 290	...	...	...
Bulgaria	...	29	74	173	...	...
Yugoslavia	2/ 2	7	21	43	...	...
Hungary	...	...	12	...	...	...
Estimated world total 5/	27,400	28,300	26,600	25,000	...	...
PRODUCTION						
	1,000 bushels	1,000 bushels	1,000 bushels	1,000 bushels	1,000 bushels	1,000 bushels
China	2/ 231,327	2/ 204,444	3/ 216,300	...	...	...
Manchuria	167,571	151,294	117,579	...	...	...
United States 4/	16,603	56,167	77,468	105,587	187,155	195,762
Canada	...	2/ 207	233	217	925	569
Chosen	20,286	2/ 19,303	...	...	...	...
Japan	12,231	12,499	...	...	...	...
Taiwan	172	2/ 151	...	...	...	...
Netherlands Indies	5,602	9,731	11,243	...	...	...
Rumania	2/ 26	1,869	3/ 3,600	...	...	...
Bulgaria	...	364	992	...	...	...
Yugoslavia	2/ 27	71	294	...	...	...
Hungary	...	...	194	...	...	...
Estimated world total 5/	455,000	458,100	440,200	446,000	...	...

1/ Preliminary.
2/ Average of less than 5 years.
3/ Unofficial estimate.
4/ Acreage harvested for beans
5/ Exclusive of the Soviet Union

Source: U. S. Department of Agriculture Statistics

Table 10. - Total acreage, acreage harvested for beans, yield, and production of soybeans in the United States, 1924-1943.

Year	Total Acreage 1/	Harvested for beans			
		Acreage	Proportion of total acreage	Yield per acre	Production
	1000 acres	1000 acres	Percent	Bushels	1000 bushels
1924	1,782	448	25.1	11.0	4,947
1925	1,785	415	23.2	11.7	4.875
1926	2,127	466	21.9	11.2	5,239
1927	2,350	568	24.2	12.2	6.938
1928	2,439	579	23.7	13.6	7.880
1929	2,807	708	25.2	13.3	9,438
1930	3,473	1,074	30.9	13.0	13,929
1931	4,304	1,141	26.5	15.1	17,260
1932	4,165	1,001	24.0	15.1	15,153
1933	3,957	1,044	26.4	12.9	13,509
1934	6,207	1,556	25.1	14.9	23,157
1935	7,503	2,915	38.9	16.8	48.901
1936	7,183	2,359	32.8	14.3	33,721
1937	7,464	2,586	34.6	17.9	46,164
1938	8,587	3,035	35.3	20.4	61,906
1939	10,920	4,315	39.5	20.9	90,141
1940	11,823	4,786	40.5	16.2	77,463
1941	11,391	5,881	51.6	18.0	105,587
1942	15,102	10,008	66.3	18.7	187,155
1943	15,854	10,684	67.4	18.1	193,125
1944 2/	14,519	10,502	72.3	18.4	192.863

1/ - Acres grown alone plus approximately one-half the interplanted acres.

2/ - Preliminary.

from approximately 25 percent of the acreage in the latter part of the 1920's to 67 percent in 1943. Two noteworthy stages of rapid expansion in production took place, one in 1935, the other in 1942.

Soybean production in the United States at present is concentrated chiefly in the North Central states. The principal soybean states in this area - Illinois, Iowa, Ohio, Indiana, and Missouri - produce approximately 90 percent of the soybeans in the United States. Illinois is, by far, the leading soybean state, accounting for over one-half of the total United States production during the 1933-42, 10-year period and for 36.5 percent in 1943 and 37 percent in 1944. Before the 1920's most of our soybean production was concentrated in the Carolinas and Virginia. However, many of the experiment stations, particularly those in the North Central States, investigated the soybean with a view toward developing varieties suited for growing in other parts of the country. This research eventually yielded several new varieties which proved highly successful and which eventually resulted in a shift of our principal soybean area from the Eastern seaboard to the North Central States. Table 11 gives the acreage harvested for beans, yield, and production of soybeans by states, for the 1933-44 period.

The practice of interplanting soybeans with other crops is confined largely to the southern and southwestern states where soybeans are utilized chiefly as a forage crop. The acreage of soybeans grown alone for all purposes, the interplanted (grown in combination with other crops) acreage, and the total equivalent solid acreage, by states, are shown in table 12.

Table 11. - Acreage harvested for beans, yield, and production of soybeans, by states, 1933-42 average, annual 1943 and 1944.

State	Acreage harvested 1/			Yield per acre			Production		
	Average: 1933-42	1943	1944	Average 1933-42	1943	1944	Average 1933-42	1943	1944
	Thousand acres			Bushels			Thousand bushels		
New York	2/ 8	20	14	2/14.6	15.0	14.0	2/ 116	300	196
N. J.	2/ 8	20	13	2/15.0	13.0	10.0	2/ 123	260	130
Pa.	2/ 10	45	34	2/16.1	14.0	14.5	2/ 168	630	493
Ohio	364	1,308	1,321	18.8	21.0	17.0	7,195	27,468	22,457
Ind.	542	1,403	1,403	16.8	18.5	16.5	9,479	25,956	23,150
Ill.	1,612	3,436	3,400	19.6	20.5	21.0	32,508	70,438	71,400
Mich.	47	103	110	14.0	15.5	14.5	687	1,596	1,595
Wis.	15	68	49	13.7	15.5	15.0	217	1,054	735
Minn.	2/ 52	246	263	2/14.5	13.5	16.5	2/ 734	3,321	4,340
Iowa	544	1,975	2,129	17.6	19.5	20.0	10,093	38,512	42,580
Mo.	147	561	606	10.4	15.5	17.5	1,678	8,696	10,605
N. Dak.	---	10	4	---	11.0	12.0	---	110	48
S. Dak.	---	23	12	---	11.0	14.0	---	253	168
Nebr.	2/ 13	82	27	2/12.0	11.5	16.0	2/ 173	943	432
Kans.	34	244	221	8.8	9.5	15.0	383	2,318	3,315
Del.	23	39	34	13.8	9.0	9.5	316	351	323
Md.	15	36	35	13.6	9.0	13.0	205	324	455
Va.	43	96	63	13.6	11.0	15.0	597	1,056	945
W. Va.	1	3	2	12.2	13.0	11.0	16	39	22
N. C.	155	257	196	11.4	9.0	10.5	1,793	2,313	2,058
S. C.	9	16	12	6.8	6.5	7.0	60	104	84
Ga.	12	13	13	6.0	6.5	6.0	72	84	78
Ky.	24	78	60	11.6	11.0	13.0	297	858	780
Tenn.	24	73	72	8.2	13.0	14.5	222	949	1,044
Ala.	15	44	47	5.9	5.5	5.5	88	242	258
Miss.	52	142	92	9.3	12.0	12.5	566	1,704	1,150
Ark.	69	267	233	12.0	9.5	15.5	905	2,536	3,612
La.	19	41	29	12.4	11.5	12.0	241	472	348
Okla.	2	10	6	7.0	5.0	8.0	19	50	48
Tex.	2/ 5	25	2	2/ 8.6	7.5	7.0	2/ 44	188	14
U. S.	3,848	10,684	10,502	17.1	18.1	18.4	68,771	193,125	192,863

1/ Equivalent solid acreage. (Acreage grown alone, with allowances for acreage grown with other crops).
2/ Short-time average.

Source: U. S. D. A. 1944 annual summary of crops.

Table 12. - U. S. Soybean acreage for all purposes, by states, 1933-42 average, annual 1943 and 1944

State	Grown alone			Interplanted			Equivalent solid 1/		
	Average 1933-42	1943	1944	Average 1933-42	1943	1944	Average 1933-42	1943	1944
	Thousand acres								
New York	13	28	20	---	---	---	13	28	20
N. J.	23	57	49	---	---	---	23	57	49
Pa.	55	127	119	---	---	---	55	127	119
Ohio	616	1,469	1,484	---	---	---	616	1,469	1,484
Ind.	1,008	1,776	1,776	---	---	---	1,008	1,776	1,776
Ill.	2,394	3,976	3,857	---	---	---	2,394	3,976	3,857
Mich.	100	137	140	---	---	---	100	137	140
Wis.	166	112	112	---	---	---	166	112	112
Minn.	156	347	357	---	---	---	156	347	357
Iowa	1,069	2,123	2,229	---	---	---	1,069	2,123	2,229
Mo.	491	750	750	67	120	68	524	810	784
N. Dak.	---	12	7	---	---	---	---	12	7
S. Dak.	2/ 8	31	14	---	---	---	2/ 8	31	14
Nebr.	15	100	30	---	---	---	15	100	30
Kans.	74	313	238	---	---	---	74	313	238
Del.	41	76	67	---	---	---	41	76	67
Md.	55	116	94	---	---	---	55	116	94
Va.	123	245	176	69	91	85	158	291	218
W. Va.	49	42	39	---	---	---	49	42	39
N. C.	296	495	361	374	430	322	483	710	522
S. C.	30	55	35	70	88	75	65	99	73
Ga.	84	117	97	86	70	50	127	152	122
Ky.	142	242	194	19	30	25	152	257	206
Tenn.	165	276	248	204	350	287	267	451	392
Ala.	244	353	290	38	28	20	263	372	300
Miss.	289	515	309	357	381	251	473	705	435
Ark.	196	446	357	275	444	320	334	668	517
La.	78	147	85	414	517	403	285	405	287
Okla.	16	35	17	3	2	2	17	36	18
Tex.	2/ 27	52	13	2/ 7	7	0	2/ 31	56	13
U. S.	8,016	14,575	13,564	1,985	2,558	1,908	9,014	15,854	14,519

1/ Acres grown alone, plus one-half the interplanted acres.
2/ Short-time average.

Source: U. S. D. A. 1944 annual summary of crops.

CROP DISPOSITION

The disposition of the soybean crop in the United States on and off the farm is shown in table 13. The proportion of the bean crop used for seed in 1924 amounted to 39 percent. For the crop of 1943 it had declined to 16 percent. This marked reduction is undoubtedly due to the development of higher yielding varieties and to the fact that more of the soybean crop is now harvested for beans.

The quantity of soybeans fed to livestock on the farm where produced has increased with the increase in production, but the proportion of the crop so used has sharply declined. Approximately 25 percent of the total soybean production was fed by farmers in the 1920's whereas in 1943 only 4 percent of the crop was so utilized on the farm where produced.

Along with increased production and expanded utilization, soybeans have become increasingly important as a cash crop. The proportion of the crop sold off the farm and the proportion crushed for oil and meal have increased rapidly. In 1924 about 60 percent of the crop was sold and about 10 percent of the quantity sold was crushed. In 1943 approximately 89 percent was sold and approximately 82 percent of that quantity was crushed.

Relative Importance as a Crop

The importance of soybeans (for beans only) in the agricultural economy of the United States is relatively small when their farm value and their contribution to cash farm income is compared to the total value and income from all farm products. Their culture and utilization, however, satisfy certain requirements which no other crop fills, consequently, they are becoming increasingly important in the organization of farming practices on Corn Belt farms. Table 14 indicates the relative importance in 1942 of soybeans as a cash crop in the United States and in the states where it is considered a major crop. In Illinois, the state of principal production, it contributed about 10 percent of the farmers' cash income, while for the country as a whole it contributed less than 2 percent.

MARKETING

The marketing of soybeans is conducted in practically the same manner and the same marketing procedure and facilities are used in assembling, storing, grading, transporting, financing, etc. as in the case of the cereal grains. Country elevators are usually the first to receive soybeans from the farmer; from there the beans may go directly to processors--some of the larger of whom operate line elevators--or to terminal elevators, commission merchants, or brokers. Many mills buy directly from the farmer.

A soybean futures market is operated by the Chicago Board of Trade, soybean meal futures market by the Memphis Merchants Exchange, and soybean oil futures market by the New York Produce Exchange.

Table 13. - Production and disposition of soybeans in the United States, 1924-1943 1/.

Crop of	Production	Disposition of soybeans on farm where produced			Disposition of soybeans sold			
		Seed	Fed to livestock	Sold	Seed	Crushing		All other uses 2/
						Quantity	Proportion of production	
	1000 bus.	1000 bus.	1000 bus.	1000 bus.	1000 bus.	1000 bus.	Percent	1000 bus.
1924	4,947	702	1,207	3,038	1,239	307	6.2	1,492
1925	4,875	783	1,174	2,918	1,553	351	7.2	1,014
1926	5,239	908	1,311	3,020	1,662	335	6.4	1,023
1927	6,938	996	1,631	4,311	1,725	559	8.1	2,027
1928	7,880	1,091	1,473	5,316	1,950	882	11.2	2,484
1929	9,438	1,541	1,717	6,140	2,270	1,666	17.7	2,204
1930	13,929	2,205	1,929	9,337	2,544	4,069	29.2	2,724
1931	17,260	2,259	1,975	12,499	2,324	4,725	27.4	5,450
1932	15,158	2,161	1,985	10,829	2,089	3,470	22.9	5,270
1933	13,509	3,067	2,108	7,972	4,434	3,054	22.6	434
1934	23,157	5,462	1,310	15,823	3,960	9,105	39.3	2,758
1935	48,901	4,626	3,537	36,215	3,544	25,181	51.5	7,490
1936	33,721	4,404	2,464	23,115	3,666	20,618	61.1	2/ 1,169
1937	46,164	5,312	3,393	36,567	4,969	30,310	65.7	1,288
1938	61,906	7,721	4,481	50,527	6,036	44,648	72.1	2/ 157
1939	90,141	9,400	5,577	76,295	6,668	56,684	62.9	12,943
1940	77,468	8,832	5,069	63,423	5,577	64,056	82.7	2/ 6,210
1941	105,587	11,044	4,013	90,530	10,028	77,131	73.0	3,371
1942 3/	187,155	10,735	6,198	170,222	11,223	132,575	70.8	26,424
1943 4/	195,762	13,557	8,364	173,841	8,414	142,256	72.7	23,171

1/ Relates to disposition of the crop specified and not to disposition within the marketing year, except "crushings" which are census data for the year beginning October. Stocks at beginning and end of each year are disregarded.

2/ This figure is a balancing item. The negative quantities are due to the fact that stocks have been disregarded in this compilation. The uses include net exports, soybeans sold from the farm and fed, soybeans used for human consumption.

3/ Revised.

4/ Preliminary (a revision in the production figure has changed it to 193,125).

Source: U. S. Dept. of Agr. and U. S. Census Bureau data.

Table 14.- Relative importance of specified farm products in the Corn Belt states. Cash income from farm marketings for calendar year 1942.

Product	Unit	United States	Illinois	Iowa	Indiana	Ohio
Soybeans	1,000 dollars	256,846	97,238	45,606	36,960	35,769
	Percent	1.67	10.10	3.71	6.81	6.19
Corn	1,000 dollars	478,284	150,114	115,815	26,358	18,234
	Percent	3.11	15.60	9.42	4.86	3.15
Wheat	1,000 dollars	837,453	13,394	4,865	11,095	28,641
	Percent	5.45	1.39	0.40	2.04	4.96
Oats, barley, grain sorghums, hay	1,000 dollars	336,742	24,521	19,069	7,427	8,378
	Percent	2.19	2.55	1.55	1.37	1.45
Rye, rice, buckwheat	1,000 dollars	106,319	146	68	251	345
	Percent	0.69	0.02	0.01	0.05	0.06
Fruit	1,000 dollars	785,529	7,631	943	3,004	12,428
	Percent	5.11	0.79	0.08	0.55	2.15
Vegetables	1,000 dollars	1,086,307	15,833	6,916	23,983	31,644
	Percent	7.07	1.65	0.56	4.42	5.48
Livestock and livestock products	1,000 dollars	8,987,175	634,467	1,019,585	416,613	410,966
	Percent	58.45	65.92	82.91	76.77	71.11
Other	1,000 dollars	2,499,699	19,057	16,744	16,964	31,483
	Percent	16.26	1.98	1.36	3.13	5.45
Total farm products	1,000 dollars	15,374,354	962,401	1,229,611	542,655	577,888
	Percent	100.00	100.00	100.00	100.00	100.00

Source: Latest revised estimates as of 8/19/44. U. S. Bureau of Agricultural Economics.

Grades

Effective September 3, 1935, grading standards* were set up by the U. S. Department of Agriculture for the grading of soybeans on a voluntary basis. This was a necessary prerequisite to the establishment October 5, 1936 by the Chicago Board of Trade of a futures trading market for soybeans.

On November 20, 1940, the inspection and grading of soybeans, when sold by grade in interstate or foreign commerce, was made mandatory under the administration of the Grain Standards Act. The U. S. official standards for soybeans, effective September 1, 1941, provide for the classification of soybeans into five classes according to color and into five numeral grades, i.e. No. 1, No. 2, No. 3, No. 4, and Sample Grade, according to minimum test weights per bushel and maximum limits for moisture, splits, damaged kernels, and foreign material other than dockage. If the beans are infested with live weevils or other insects injurious to stored grain, the special grade designation "weevily", is affixed to the numerical grade otherwise applicable. If the dockage (foreign material of a type readily removable) present amounts to one percent or more, the word "Dockage," together with the percentage thereof is added to the grade designation.

The five classes of soybeans are: Class I, Yellow; Class II, Green; Class III, Brown; Class IV, Black; and Class V, Mixed. The Mixed soybeans class includes mixtures of other classes as well as bicolored soybeans.

International Trade

International trading in soybeans has averaged less than 100 million bushels a year. Manchuria has been the chief exporting country, and Germany, Japan, and Denmark have been the leading importing countries. The United States, between 1924 and 1931, imported on the average about 68,000 bushels of soybeans annually. Beginning in 1931, the United States became a net exporter and reached its highest point in this trade in 1939 when exports amounted to 11.8 million bushels. This latter development was a direct result of the cutting off of Manchurian trade because of World War II, European countries being forced to turn to the United States for their soybean supplies. Germany, realizing the necessity for obtaining soybeans to help her war food program, originally arranged for the Russian government to ship considerable quantities of Manchurian soybeans across the Trans-Siberian Railway, but few, if any,

---

* For details of these standards see U. S. Dept. Agr. Handbook of Official Grain Standards of the U. S. U.S.G.S.A. Form No. 90, Revised 1941

of these shipments ever arrived in Germany prior to the initiation of Russo-German hostilities. Germany employed similar practices during World War I, on one occasion purchasing a very large proportion of our North Carolina soybean production at fabulous prices prior to our entering that conflict.

Prices

Soybean prices vary quite widely by areas from year to year, and by use made of the crop. In the principal surplus producing states, Illinois, Iowa, Ohio, and Indiana, where most of the soybeans produced are used for processing, prices are lower than in the less-important producing areas, where most of the beans sold are used for seed. Data showing the average price per bushel received by farmers for soybeans in the United States by months from 1934 to 1944, are shown in table 15. The average price per bushel received by farmers for soybeans, by states, from 1933 to 1943, are shown in table 16.

Under normal marketing conditions, the prices of soybean oil and oil meal are the most important factors affecting the price of soybeans, i.e., these values plus processing margins determine the prices that processors are able to offer for industrial beans.* On the other hand, the price of soybean oil and oil meal, are influenced by the supplies and prices of competing products. Lard and cottonseed and peanut oils in the edible-fat field and linseed oil in the drying-oil field exert an important influence on the price of soybean oil. Similarly, the price of soybean oil meal is affected by supplies and prices of cottonseed and linseed meals, the former being especially important because of its large production.

There is usually a seasonal rise in soybean prices during the spring months (April through June) reflecting the demand for soybeans for planting pur poses. This rise in price, which is independent of oil and meal values, usually causes processors' margins to be smaller during this period.

Table 17 shows the average monthly prices of soybean oil and meal and the farm price of soybeans for the crop years 1938-39, 1939-40, 1940-41, 1941-42, 1942-43 and 1943-44 by months.

The supply situation of soybeans also affects their movement. Until the marketing year 1942-43, the industry's capacity for processing beans was greater than the annual supply available for crushing. Consequently, surplus stocks at the end of the marketing year were negligible, and in some instances processors were forced to bid against each other inordinately

* In some cases, processors are willing to operate at a loss for short periods of time, rather than lose markets which have been built up for their products. Also, the expense of closing down a large plant may be greater than that sustained by temporary uneconomic operation.

Table 15. - Avdrage soybean price per bushel received by farmers, United States, 1926-44

Year beginning October	Oct. 15	Nov. 15	Dec. 15	Jan. 15	Feb. 15	Mar. 15	Apr. 15	May 15	June 15	July 15	Aug. 15	Sept. 15	Season average price
	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.
1926	1.97	1.85	1.83	1.90	2.03	1.98	2.07	2.15	2.20	2.14	2.06	1.91	2.01
1927	1.86	1.70	1.61	1.70	1.69	1.85	1.93	2.06	2.13	2.12	2.01	1.89	1.81
1928	1.72	1.69	1.70	1.82	1.93	2.13	2.19	2.30	2.41	2.46	2.15	1.87	1.88
1929	1.79	1.70	1.73	1.85	1.91	2.00	2.07	2.11	2.16	1.96	1.90	1.80	1.88
1930	1.64	1.48	1.44	1.46	1.40	1.42	1.38	1.39	1.29	1.12	.94	.82	1.37
1931	.52	.47	.47	.47	.48	.51	.51	.52	.51	.47	.47	.47	.50
1932	.46	.45	.44	.45	.45	.48	.58	.86	.98	1.04	.94	.85	.54
1933	.68	.69	.73	.81	1.01	1.16	1.26	1.25	1.45	1.54	1.25	1.05	.94
1934	.95	.89	1.11	1.19	1.27	1.20	1.18	1.21	1.19	.98	.73	.69	.99
1935	.68	.69	.72	.76	.77	.78	.78	.83	.85	1.05	1.19	1.10	.73
1936	1.07	1.12	1.30	1.43	1.50	1.52	1.66	1.74	1.50	1.32	1.02	.90	1.27
1937	.86	.83	.83	.88	.93	.89	.85	.87	.86	.85	.75	.71	.85
1938	.64	.63	.67	.72	.69	.73	.78	.87	.83	.75	.64	.73	.67
1939	.73	.82	.97	1.03	.96	1.01	1.00	.96	.79	.73	.67	.69	.81
1940	.67	.84	.81	.89	.84	.89	1.07	1.19	1.23	1.30	1.29	1.61	.90
1941	1.42	1.43	1.47	1.65	1.78	1.79	1.76	1.73	1.63	1.62	1.58	1.57	1.55
1942	1.58	1.58	1.59	1.59	1.60	1.65	1.67	1.72	1.73	1.70	1.68	1.69	1.61
1943	1.80	1.80	1.81	1.82	1.85	1.89	1.91	1.93	1.93	1.91	1.90	1.93	---
1944	2.04	2.05	2.05	2.06	2.10	2.13							

Source: Agricultural Marketing Service: Based on returns from special price reporters. Monthly prices, by States, weighted by production to obtain monthly prices for the United States. Season average prices for each State based on monthly prices weighted by estimates of monthly sales during the crop marketing season. Season average prices, by States, weighted by production to obtain United States season average. U.S.D.A. Agricultural Statistics.

Table 16. - Average soybean price per bushel received by farmers, by states, 1933-1943

State	Average price per bushel received by farmers for crop of -										
	1933	1934	1935	1936	1937	1938	1939	1940	1941	1942[1]	1943[1,2]
	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.	Dol.
New York	---	1.42	.95	1.77	1.38	1.10	1.19	1.11	1.70	1.72	1.87
New Jersey	---	---	---	---	---	1.06	1.13	1.19	1.70	1.76	1.86
Pennsylvania	---	1.36	.92	1.87	1.35	1.05	1.07	1.00	1.60	1.66	1.85
Ohio	.89	1.14	.68	1.32	.82	.66	.82	.91	1.55	1.61	1.81
Indiana	.86	.98	.70	1.26	.81	.64	.81	.95	1.55	1.61	1.81
Illinois	.71	.86	.68	1.18	.81	.64	.77	.85	1.55	1.60	1.81
Michigan	.84	1.08	.80	1.38	.84	.73	.90	1.00	1.55	1.61	1.82
Wisconsin	1.30	1.32	1.00	1.57	1.00	.85	.95	1.11	1.60	1.58	1.83
Minnesota	---	---	---	---	---	.76	.88	.98	1.55	1.49	1.81
Iowa	1.02	1.15	.67	1.29	.82	.67	.81	.88	1.50	1.58	1.83
Missouri	1.06	1.45	1.07	1.74	1.11	.84	1.00	1.13	1.60	1.60	1.84
Kansas	1.14	1.39	1.10	1.57	.96	.99	1.05	.96	1.55	1.59	1.82
Delaware	1.17	1.07	1.90	1.90	.86	.65	.91	.90	1.40	1.46	1.92
Maryland	1.23	1.09	1.02	2.03	.90	.73	1.00	.97	1.50	1.53	1.94
Virginia	1.17	1.19	.93	1.58	1.04	.82	.99	.88	1.50	1.61	1.94
W. Virginia	1.75	2.03	1.69	1.56	1.53	1.25	1.34	1.50	1.70	1.89	2.19
N. Carolina	1.26	1.19	.90	1.34	.99	.77	.94	.83	1.45	1.64	1.90
S. Carolina	1.67	1.96	1.73	2.01	1.53	1.53	1.81	1.53	2.25	2.56	3.19
Georgia	1.75	2.00	2.35	2.33	2.08	2.19	2.17	2.19	2.30	2.61	3.24
Kentucky	1.35	1.36	1.21	2.03	1.15	.92	.97	1.12	1.60	1.49	1.81
Tennessee	1.40	1.36	1.43	1.83	1.25	1.11	1.26	1.13	1.70	1.85	2.25
Alabama	1.69	1.54	2.00	1.93	1.57	2.14	2.43	2.33	2.20	2.58	3.21
Mississippi	1.93	1.99	1.88	2.22	1.54	1.42	1.46	1.42	1.95	1.86	2.39
Arkansas	1.68	2.05	1.95	2.17	1.40	.97	1.15	1.10	1.55	1.66	2.03
Louisiana	2.01	2.54	1.99	2.15	1.41	1.36	1.18	1.46	2.00	1.89	2.86
Oklahoma	1.42	1.88	1.90	2.19	1.55	1.34	1.58	1.44	1.75	1.80	1.81
Texas	---	1.60	1.16	1.80	1.64	1.61	1.69	1.75	1.80	1.66	1.86

1/ Preliminary.
2/ Includes an allowance for unredeemed loans at average loan value.

Compiled from U.S.D.A. Agricultural Statistics.

Table 17. - Average monthly prices: soybean oil, Midwestern mills; soybean meal, Chicago; and soybeans, United States farm

Crop year and month	Prices: Oil, domestic crude, in tank cars	Prices: Meal, 41% protein	Prices: Soybeans	Crop year and month	Prices: Oil, domestic crude, in tank cars	Prices: Meal, 41% protein	Prices: Soybeans
	Cents per pound	Dollars per ton	Dollars per bushel		Cents per pound	Dollars per ton	Dollars per bushel
1938-39				1941-42			
October	5.03	24.60	.64	October	10.38	37.95	1.42
November	5.03	24.40	.63	November	9.83	39.10	1.43
December	5.14	26.20	.67	December	10.08	42.50	1.47
January	4.97	26.30	.72	January	11.44	46.45	1.65
February	4.76	24.70	.69	February	11.72	46.45	1.78
March	4.91	24.45	.73	March	11.75	44.85	1.79
April	4.72	24.70	.78	April	11.75	41.00	1.76
May	4.92	26.30	.87	May	11.75	38.30	1.73
June	4.86	25.95	.83	June	11.60	37.90	1.63
July	4.34	24.70	.75	July	11.24	41.30	1.62
August	4.17	25.70	.64	August	11.44	42.60	1.58
September	5.11	33.70	.73	September	11.66	43.50	1.57
1939-40				1942-43			
October	4.94	28.30	.73	October	11.75	42.70	1.58
November	4.83	32.70	.82	November	11.75	46.60	1.58
December	5.12	34.95	.97	December	11.75	39.00	1.59
January	5.33	33.90	1.03	January	11.75	39.35	1.59
February	5.40	29.95	.96	February	11.75	39.60	1.60
March	5.73	30.45	1.01	March	11.75	40.60	1.65
April	5.51	29.65	1.00	April	11.75	40.60	1.67
May	5.33	28.65	.96	May	11.75	40.55	1.72
June	4.72	24.40	.79	June	11.75	40.40	1.73
July	4.72	22.25	.73	July	11.75	40.40	1.70
August	4.36	24.60	.67	August	11.75	51.90	1.68
September	4.11	27.00	.69	September	11.75	51.90	1.69
1940-41				1943-44			
October	3.91	25.90	.67	October	11.75	51.90	1.80
November	4.29	30.50	.84	November	11.75	51.90	1.80
December	4.48	29.60	.81	December	11.75	51.90	1.81
January	5.12	29.75	.89	January	11.80	51.90	1.82
February	5.06	26.60	.84	February	11.80	51.90	1.85
March	6.03	26.85	.89	March	11.80	51.90	1.89
April	7.58	27.50	1.07	April	11.80	51.90	1.91
May	8.68	28.10	1.19	May	11.80	51.90	1.93
June	9.62	29.70	1.23	June	11.80	51.90	1.93
July	9.79	33.80	1.30	July	11.80	51.90	1.91
August	9.47	36.20	1.29	August	11.80	51.90	1.90
September	10.50	41.40	1.61	September	11.80	52.00	1.93

Source: U. S. Dept. of Agr. Statistics.

at certain times during the year in order to obtain enough beans to keep operating. This situation has had a tendency to increase speculative activity by farmers and the public.

UTILIZATION OF WHOLE SOYBEANS

Seed

Each year a certain portion of the soybean production must be reserved for the next year's seeding operations. Some of this seed is required for the production of beans, some for the production of green cover crop for turning under as a soil builder. The quantity, viability, method of planting, and similar factors have been discussed in previous sections. In the period 1930-39 the quantity of seed used per planted acre for all purposes (interplanted acres counted as one-half) averaged 72 pounds per acre. In 1941 it averaged 76.2 pounds and in 1942, 79.2 pounds. The total quantity of seed used annually since 1930 has ranged from 3,811,000 in 1930 to 20,331,000 bushels in 1942.

Feed

Soybeans, like other grains, can be utilized as feed in several different forms. The entire bean, either in its whole form or cracked or ground, or the residue after oil processing can be utilized. Also the entire plants can be harvested, when the beans are about half-developed, and used as hay.

Whole soybeans can be fed to livestock to provide the protein supplement in feed mixtures, but their large content of oil, when fed in too large proportions, results in soft fat in hogs 7/ and soft butter 8/ when fed to dairy cattle.

7/ W. E. Carroll, Soybean Oilmeal, a Valuable Protein supplement for Swine, Animal Husbandry Department, University of Illinois, AH1012 (1940)

8/ Utilizing the Soybean in Livestock Feeding. University of Illinois Agricultural Experiment Station. Circ. 369 (1937)

The Iowa State College of Agriculture 9/ claims that, according to their experiments, soybeans have a value as a protein supplement in the dairy ration at least equal, if not superior, to linseed oilmeal and cottonseed meal, the two concentrated protein supplements most commonly used in Iowa.

Until comparatively recently, the feeding of unprocessed soybeans was considered conducive to scouring in dairy cattle, but more recent investigators have failed to confirm this. However, some of the essential amino acids in soybean protein are not readily available to "critical" animals whose demands for protein are rather exacting. This class of animals includes hogs, lambs, poultry, calves, dogs, and fur-bearing animals; and in order for these to use soybean protein efficiently it is necessary to apply a heat treatment, apparently to make the cystine and methionine available. The relative protein efficiency of raw soybeans may be only 40 percent, but the cooked or toasted soybean protein exhibits efficiencies of 85 to 95 percent. It is for this reason that properly processed soybean oilmeal is greatly preferred by feeders instead of raw soybeans.

The quantity of soybeans fed to livestock on farms where produced amounted to about 5 percent of the total production in 1941, or about 5.6 million bushels. The quantities fed in 1939 and 1940 were 5.6 and 5.1 million bushels, respectively.

Discussion of utilization of soybean oil-cake meal for feed appears in a later section on the utilization of the protein fraction.

Soybeans have increased in importance as a hay and seed crop during the past decade. If the plants are cut when the seeds are about half developed and the plants properly cured, a hay which has a high content of digestible protein is obtained. This hay can be fed profitably to all kinds of livestock, makes an excellent winter ration for young cattle, sheep, horses, and mules, and has been used to good advantage for hogs and poultry. Soybean hay, produced on the farm where it is fed, is a cheap source of protein for balancing feeds for livestock, milk, and butter production. Soybeans usually yield from 1 to 3 tons of hay to the acre, and occasionally 4 to 5, depending upon the fertility of the soil and upon the season. During the 10-year period, 1930-39, the average production of hay was 4,098,000 tons; in 1941, 4,779,000 tons; and in 1942, 3,945,000 tons. The drop in 1942 was, no doubt, occasioned by the necessity of using all possible soybeans for processing into oil. Marketing of soybean and soybean mixed hay is done under the uniform standards as set forth in the handbook of Official Hay Standards prepared by the U.S.D.A.

The development of more economical methods and suitable machinery in harvesting and handling the crop has been one of the chief factors in increased seed production. In regions where proper harvesting equipment is readily available and where there is an established market for soybeans it is more profitable to harvest the beans for processing into oil and feed than to harvest the crop as hay.

Food

Although soybeans were first grown in this country as a forage crop, certain edible varieties are now coming into use as a valuable addition to our list of vegetables, both in the fresh and dry form. The fresh, or green shelled, beans are very rich in vitamin A and are also a very good source of vitamin B_1 and of riboflavin. The dry soybeans, however, are not good sources of vitamin B_1 and riboflavin. Also they contain considerably less vitamin A than the fresh green soybeans. They are richer in protein and fat than other common table beans. This protein consists of 9% lysine, one of the 10 amino acids known to be necessary for growth and maintenance of body tissues, whereas the gluten of wheat flour consists of only 2% of this essential amino acid. On the average, dry soybeans contain about 1-1/2 times as much protein and 12 times as much fat as other dry beans. The carbohydrate content of soybeans is comparatively low, about 12 percent available carbohydrates in the dry beans and 6 percent in the green shelled soybeans. Both the fresh and the dry beans are good sources of the mineral elements, calcium, phosphorus, and iron,

From the dry soybeans come a number of products, some of which are produced in only small quantities. These include flour and grits (made either from the whole beans or from oilmeal), "milk," curd, and soy sauce. Because of the glutamic acid contained in the protein, soybeans are a possible source of mono-sodium glutamate, a material used for imparting meat flavors to foods, but present commercial production is derived from wheat protein because glutamic acid is more readily available in relatively concentrated form as the byproduct of certain wheat processing operations. Products made from whole soybeans are similar to the dry soybeans in food value while oil-cake meal products resulting from oil processing are much lower in fat content and higher in protein and carbohydrate. In general, products derived from soybeans and soybean oilmeal are not used alone but are used to raise the protein content of other foods. They can be blended with wheat flour for use in bakery products, mixed with breakfast cereals, used in soup, in preparations of dehydrated and dry soup concentrates, and in prepared meat products as an extender to maintain or raise the protein level.

Normally, soybean processing has as its objective the production of oil and meal, using expellers, screw presses, solvent extractors or hydraulic presses. Prior to World War II, nearly all soybeans entering commercial channels were consumed in this manner, but relatively small amounts were used to manufacture soy flour for human consumption. Some types are made in a manner quite similar to the processing methods used for oil and meal, but others are produced by distinctly different procedures. Much of the soy flour is manufactured as a side-line by processors whose principal business is the production of oil and meal, but practices in soy flour grinding are somewhat unique and merit separate treatment in any discussion of the soybean processing industry.

Before World War II, approximately 25 million pounds of soy flour were used each year in baked goods, meat extenders, pet feeds, and similar products. War-time shortages of meats focused attention upon soy flour as a replacement material for a portion of the usual proteins in human diets, and there was accordingly a tremendous increase in its production for both domestic and overseas use.

For purposes of strengthening wartime diets nutritionally the War Food Administration encouraged the voluntary inclusion, in the form of either grits or flour, of small percentages of soy products in bread, soap powders, macaroni, breakfast cereals, pancake flours, confections, and sausages.

Soy flour is made in many forms, but is of three general types, "low-fat", "medium-fat", and "full-fat". The full-fat type is made by grinding whole soybeans, the medium-fat by pressing the beans in expellers or screw presses before grinding, and the low-fat type by grinding meal from which the oil has been solvent extracted. Soy grits are a product quite similar in composition to soy flour but not ground to a fine powder. They are used mainly in meats, as extenders, and in various confections and baked goods as a garnish.

The essential steps in the manufacture of soy flour are, removal of the hulls, debittering, grinding, and sifting or bolting, but not always in the order mentioned. The beans are dehulled by coarsely cracking, followed by aspiration or by some similar separation method. Commercial varieties of beans have a characteristic flavor which, though not particularly disagreeable, it is preferable to remove. This step in the process is known as debittering and is accomplished by a wide variety of methods, such as treatment with heat, steam, and various other gases. For full-fat flour, the beans are ground in roller mills and the product is bolted through silk, much the same as in ordinary flour milling. In the production of medium-fat and low-fat flours, the dehulled and debittered beans are passed through expellers or solvent extractors before the final milling. In all types, the requirement is that 95 percent shall pass through the U. S. Standard No. 120 woven wire cloth sieve.

The production of soy flour requires considerably more care than that of soybean oil meal intended for animal feed only, for the beans must be selected for quality and, as in all food processing plants, sanitary precautions must be observed. Most, but not all, soy flour is manufactured in mills which also process soybeans for oil and oilmeal feed. In expeller type plants, one or more expellers or screw presses are frequently operated separately from the rest, and these crush the dehulled and debittered beans from which low-fat flour is to be made. When low-fat flour is made by solvent extraction, the usual practice is to operate the extractor alternately, a few days on flour and a few on meal, depending upon the relative tonnages of meal and flour required. The oil obtained in making medium-fat and low-fat flours is marketed in the same manner as that obtained from meal production, the two usually being mixed as they are produced. The use of soy flour, particularly of the medium-fat and low-fat types, is discussed further in a later section dealing with the utilization of soybean protein.

INDUSTRIAL DEVELOPMENT

Inasmuch as the greater part of soybean production is processed by a specialized industry before it is consumed, soybeans are predominately a cash (see tables 13 and 14) crop. Consequently, the agricultural expansion of soybean culture in the United States is closely associated with the development of the soybean processing industry, and both phases owe much of their early expansion and development to the foresight, cooperation, and aggressiveness of a few agricultural and business leaders.

History of Industry

The first soybeans processed in this country were imported from Manchuria in 1911 and crushed in a small mill in Seattle, Washington. Domestic soybeans were first crushed commercially at Elizabeth City, North Carolina in 1915. As North Carolina led in the production of soybeans at that time, two other mills in the state, one at Winterville, the other at Washington, soon began crushing soybeans. All of these enterprises, however, were on a very small scale and lasted for only a short period.

During World War I the serious shortage of fats and oils made necessary the importation of large quantities of soybean oil. Most of these imports were from Manchuria and were frequently of very low quality. After the War, the low quality of imported oil, together with the increasing popularity of soybeans as a leguminous forage and fertilizer crop, stimulated interest in soybeans both agriculturally and industrially.

In the 1917-18 season it was decided to attempt soybean processing in a small mill operated by the Chicago Heights Oil Manufacturing Co., Chicago Heights, Illinois, which was then operating with hydraulic presses on linseed and with expeller equipment on corn germs and mustard seeds. However, the demand for soybeans that fall for planting purposes was so great that only a very small quantity of soybeans was obtained by the mill. This small quantity was used to determine methods of grinding and drying. Similarly a large demand for soybeans for seed the following year again prevented the obtaining of adequate supplies locally, so in 1921 the mill bought 10 carloads of soybeans in North Carolina and Virginia from which it produced four carloads of oil with its expeller equipment.

In 1922 and 1923 enough soybeans were accumulated by the mill to try out its hydraulic presses and these also worked satisfactorily. It was then evident that from the technical standpoint soybean processing could be successful in this country. However, in order to place the processing of soybeans on a commercial basis, it was necessary that assured markets for the oil and meal be found and that an adequate supply of beans be available for processing. To accomplish this, a campaign to enlighten potential consumers concerning the merits of soybean oil and meal and a program of research to extend the applicability of these products were undertaken by processors. Simultaneously better-adapted and higher-yielding soybean varieties were being developed by the U. S. Department of Agriculture and agricultural experiment stations, and farmers were being encouraged to grow more beans for crushing.

The A. E. Staley Manufacturing Company of Decatur, Illinois, a long-established manufacturer of corn products, entered the soybean processing field in 1922 and did much toward developing the market for soybeans and in encouraging farmers to grow soybeans for crushing. Many problems had to be overcome, however, in both production and marketing before the soybean processing industry became what it is today. From the 1924 crop, the first year for which figures are available, 307,000 bushels of soybeans were crushed in this country. For the next 10 years soybean processing increased steadily but not rapidly (see table 13); for example, in 1933, 3,054,000 bushels were processed. The industry expanded as other large concerns (such as Allied Mills, Inc., Archer-Daniels-Midland Co., Central Soya Co., Glidden Co., Ralston Purina Co., Spencer Kellogg and Sons, Inc., Swift and Co., Etc.) entered the industry, and the recent increase in soybean oil and meal production has been phenomenal. From the 1941 crop, 706,661,000 pounds of soybean oil and approximately 1,845,000 tons of meal were produced from the crushing of 77,131 bushels of soybeans. Estimates of the amount of oil produced from the 1942 crop of soybeans are given as 1,198,207,000 pounds, and 3,179,000 tons of meal from 132,575,000 bushels of soybeans.

Considerable assistance has been given to the industry in recent years, particularly in the field of industrial utilization of soybean products, by the United States Regional Soybean Industrial Products Laboratory established at Urbana, Illinois in 1936 under authority of the Bankhead-Jones Act of 1935. The chemical and engineering sections of this Laboratory were transferred to Peoria, Illinois on July 1, 1942 and absorbed by the Northern Regional Research Laboratory.

Processing

Growth of the soybean processing industry in the United States has been extremely rapid, particularly when contrasted with the bean crushing industry of Manchuria which is still in rather primative stage of technological development. Of particular interest is the manner in which oilseed processing technology has been modified as a result of developments in the soybean industry.

Immediately after World War I, Germany Undertook the processing of soybeans, imported from Manchuria, on a considerable scale. The oil was in great demand for food uses, and the protein meal was needed for livestock production. The necessity for recovering maximum possible amounts of oil led to the development of highly efficient solvent extraction systems which were installed in tremendous mills at Hamburg and other oilseed crushing centers.

In the United States, on the other hand, where domestic production of fats and oils is more nearly on a self-sufficient basis the soybean industry grew up around the expeller, which is a continuous press, somewhat less efficient in oil removal than solvent equipment.

Attempts were made as early as 1923 to introduce solvent extraction to the American soybean industry, but without success. The principal reason for early failures was the small supply of soybeans, for this country had not undertaken the importation of Manchurian soybeans on a scale comparable with that adopted by Germany, nor had there been any urgent market demand for soybean oil and meal to justify immediate domestic production on a tremendous scale. The superiority of the German oilseed extraction system could not be denied, however, and at least one short-lived installation of German-built soybean extraction equipment was made in this country in 1924. It was not until ten years later, however, that the first permanent solvent type soybean mills were built in this country, and they were likewise of German manufacture. As a matter of fact, German extraction systems are now used the world over, and many of their desirable features are incorporated in American-built machinery which has subsequently come onto the market.

Derived Products

Briefly, soybeans are processed in three ways, mechanical pressing, solvent extraction, and grinding undefatted beans. By far the greater part of the soybean crop is pressed or solvent extracted to produce oil and oilmeal, but a certain amount of pressing and extraction is conducted to make medium-fat and low-fat flour, plus some oil. In addition, a part of the crop is ground without prior removal of the oil, the products being either full-fat soy flour or soybean meal, depending on whether it is destined for human or animal consumption. These products and the processes used in their manufacturing are shown in chart form in Figure 2, page 45.

Production of Oil and Meal

Soybeans which enter commercial channels are nearly all processed with the objective of obtaining the oil, leaving a high protein residue which can be used for stock feed or for flour. When the residue is destined for stock feeding the operation is known as "processing for meal." On the other hand, if the residue is intended for flour, the analogous term is "processing for flour." The procedure is somewhat different in the two cases.

There are three methods in common use for processing soybeans to yield oil and meal, namely, continuous pressing (expellers and screw presses), hydraulic pressing, and solvent extraction. At the present time the use of expellers and screw presses is by far the most common. Solvent extraction is used to a lesser extent but is rapidly gaining in importance. In years past, hydraulic presses were widely used, but their use is becoming less

- Mechanical pressing
  - for meal
    - 9 pounds of crude soybean oil
    - 48 pounds of "old process" soybean oil-meal, 41 percent protein
    - Approximately 3 pounds shrinkage
  - for flour
    - 7 pounds crude soybean oil
    - 44 pounds medium-fat soy flour
    - 9 pounds soybean millfeed and shrinkage
- Solvent extraction
  - for meal
    - 11 pounds crude soybean oil
    - 46 pounds of "new process" soybean oil meal, 44 percent protein
    - Approximately 3 pounds shrinkage
  - for flour
    - 11 pounds of crude soybean oil
    - 40 pounds of low-fat soy flour
    - 9 pounds soybean millfeed and shrinkage
- Grinding whole soybeans
  - for flour
    - 52 pounds of full-fat soy flour
    - 8 pounds of soybean millfeed and shrinkage
  - for feed
    - 59 pounds of soybean meal
    - Approximately 1 pound shrinkage

Figure 2. Products derived from processing 1 bushel (60 pounds) of soybeans by various methods.

common each year. As a war emergency measure, however, much soybean processing is now being conducted in hydraulic presses. In the Orient, Hydraulic presses and similar equipment are the only types of soybean processing machinery ordinarily used. In Europe solvent extraction is relied upon almost exclusively. In this country all three methods are employed to a considerable extent, as shown by the data in table 18, page 55.

American mills which use hydraulic presses are or have been for the most part engaged primarily in crushing other oil seeds, such as cottonseed and linseed. Such mills can be easily adapted to soybean crushing, but the unit crushing costs are said to be higher than those encountered either in the continuous press or the solvent type mills. These higher costs are due largely to the increased amount of hand labor required for a batch type of operation. It is for this reason that, except for the unusual condition created by a war-time shortage of oilseed processing facilities, the hydraulic press is rapidly becoming obsolete in the soybean crushing industry.

In the hydraulic press type of processing, the beans are ground and then mashed into thin flakes by passing them repeatedly between heavy steel rolls. They are then cooked in special heating chambers which are known as "stack cookers," after which the hot flakes are formed into rectangular cakes and wrapped with a hair or wool mat. These wrapped cakes are inserted between the plates of a hydraulic press, there being openings for a large number of them, and pressure is applied. A drainage or compression time of 15-30 minutes is usually allowed, and the oil exudes from the cakes and runs into a trough around the bottom of the press. After drainage is complete, the pressure is released, the cakes are removed, the cloths are stripped from them, and the cake edges are trimmed off for repressing because they contain considerably more oil than the bulk of the cake. The rectangular press cakes, resembling flat boards, are ground to meal at the mill or are shipped, as is, to feed manufacturing companies.

When continuous presses are used, the beans are rather coarsely cracked and dried to a moisture content of 2 or 3 percent. They are then conveyed to a tempering apparatus which is mounted about the expeller or screw press and in which they are held at a relatively high temperature in order to cook the protein and to equalize temperature distribution in individual particles. The hot, granulated material is then fed into the pressure zone of the expeller or screw press in which it is compressed by means of a powerful rotating screw and forced through a compression chamber, consisting of a cylindrical cage composed of longitudinal steel bars spaced a few thousandths of an inch apart. Tremendous pressures are developed in the cylinder both because of the special design of the worm and because of an adjustable constriction at the exit end of the chamber. Under the influence of high temperature and high pressure the oil is squeezed out of the beans and escapes from the compressed material by flowing out through the slots between the bars. The residual material is forced on through the cylinder and is discharged as irregularly shaped fragments containing approximately 4 percent oil. It is cooled and ground to produce soybean oil meal, as distinguished in the trade from soybean meal. The latter consists of ground soybeans from which the oil has not been removed. The crude oil is screened and then clarified by filtration before storage in outside tanks and subsequent shipment to the refinery.

In the solvent extraction of oil from soybeans as carried out in this country, the soybeans are cracked and their moisture content is adjusted to approximately 12 percent. They are then rolled into thin flakes by passing them once between large steel rolls, and they are then passed through the extraction apparatus in which the oil is leached out by means of a fat solvent. Many kinds of apparatus are in use for providing the necessary contact between flakes and solvents. Some use screw conveyors, some use drag-link conveyors, and others use moving chains of baskets containing the material to be extracted. In all of these apparatuses the flow is counter-current; that is, the oleaginous material passes in one direction, being continuously washed by a stream of solvent passing in the opposite direction. The fresh flakes are treated with solvents containing considerable oil immediately upon entering the apparatus, but as they progress through the chamber the solvent encountered is progressively fresher.

The residual solids are allowed to drain and are then discharged from the extractor into driers which expel all of the volatile solvents, leaving a meal containing approximately 1 percent or less of oil. This material is usually given a supplementary toasting in which it is heated at a relatively high temperature and in the presence of moisture for 1 to 2 hours. This treatment produces a brown color and pleasant flavor and odor which greatly add to its salability to the feed industries. The solution of oil in the solvent which leaves the extraction apparatus is known as "miscella." It is filtered, and then most of the solvent is removed by means of an evaporator or a series of evaporators, some having rather special design. The final traces of solvents are expelled by scrubbing with steam. In many mills, the scrubbing is so effected that excess water remains in the oil and aids in hydrating the phosphatides so that they can be readily separated either by settling or by centrifuging. These are subsequently purified and sold as commercial lecithin.

Considerations in Determining Size, Type, and Location of Plants

Processing costs

There are very few published data on the costs of installing and operating soybean processing mills, and the best sources of such information are the manufacturers of equipment used in the process. It is usually a simple matter to determine the probable costs of raw materials and the yields and prices of the finished products for any chosen locality, but the operating expenses vary considerably, depending upon the type of process, size of installation, continuity of operations, and other factors. Typical yields and values of the products obtained per bushel of soybeans at a typical expeller type mill in 1943-44 were as follows:

Quantity and value of products from one bushel of soybeans:

Oil -- 8.87 lbs. at 11-3/4 cents - -	$1.042
Meal - 47.37 lbs. at 2-1/4 cents- - -	1.066
Total value of products	$2.108
Cost of one bushel of soybeans delivered and stored at plant - - - - - - - - - - - -	1.880
Operating margin per bushel	$0.228

The approximately 23 cents per bushel "spread" between prices of raw materials and products would have to cover all operating expenses, overhead, and profits. The amount of this "spread" is normally subject to market conditions, and for several years prior to World War II, it fluctuated between 14 and 20 cents per bushel for typical expeller type mills located in the heart of the soybean producing area. World War II conditions resulted in the establishing of controlled markets, and the soybean industry operating under government contracts, with prices adjusted to allow each mill a fixed operating margin. The data just presented should therefore be considered only as an example of usual soybean milling yields, for the reason that purchase prices of the soybeans may be adjusted to provide the operating margin to which a given mill is entitled.

The approximate operating margins allowed various soybean mills under the 1943-44 government contract provided some measure of comparison between various types of mills. The schedule classified plants three ways according to type and three ways according to size as follows:

	Operating margin allowed - cents per bushel
Solvent type:	
Large	29
Medium	30
Small	31
Expeller and screw press types:	
Large	24
Medium	26
Small	28
Hydraulic press type:	
Large	29
Medium	30
Small	31

Small mills are those under 3,000 bushels per day, medium mills are 3,000 to 6,000 bushels per day, and large mills are over 6,000 bushels per day.

An analysis of the bare operating costs in solvent and expeller type soybean mills is given by Bilbe 10/, who quotes 9.2 cents per bushel in a 120-ton solvent mill and 3.5 cents in an expeller or screw press plant of comparable size. These figures, which of course do not include administrative and sales expense, profit, and certain other minor items of overhead, are based upon utility and labor prices of that date. The article in question should be consulted for a more detailed explanation of the cost analysis, for the data presented can readily be altered appropriately to obtain estimates of operating costs in mills of different sizes than those described, for comparative purposes. Although the solvent system may appear slightly more expensive to install and operate, the apparently higher initial cost and operating expense are usually more than compensated for by the extra yield of oil realized in the extraction process.

A complete study of operating costs in mills of various sizes reveals that it is much cheaper to crush soybeans in large plants than in small ones. The principal items contributing to higher unit operating costs in small plants are wages and overhead of all types. The so-called fixed charges, such as taxes, insurance, depreciation, etc., are particularly high on a cost-per-bushel basis of the mill operates only part of the year. It is for this reason that, in the larger plants, every effort is made to keep the plant running for practically 12 months of the year. Shut-downs are costly and should be avoided if it is at all possible.

Size of Plant

No general statement can be made in regard to the smallest size soybean mill that is practicable, for the answer to this question varies from location in accordance with many economic factors, several of which will presently be discussed. In most cases, but not always, it is necessary to have available a supply of soybeans sufficient to assure nearly year-round operation. The quantity depends, of course, upon the size of the plant.

The one-expeller type of mill has proved perfectly satisfactory in many locations for small-scale operation. Crushing about 20 tons of soybeans per day, it would require approximately 200,000 bushels to operate for 300 days. In the industry, there are expeller type plants of all sizes, ranging in capacity from 500 to 30,000 bushels per day; but one having 4 to 8 expellers or screw presses and crushing 2,500 to 5,000 bushels per day is considered by many to be typical. Mills of this size are located rather generally throughout the soybean belt.

10/ Bilbe, C. W. Continuous Solvent Extraction of Vegetable Oils. Mech. Eng. 63 357-60 (1941) Cott. and Cott. Oil Press. 42 (12), A-8, A-9, A-12 (1941).

Much has been written and spoken in favor of the ultra-small soybean processing installation, which can be installed in one's barn, and also of some of the slightly larger versions, operated to serve a small community. A great deal can be said both in favor of and against such operations, but prior to the time when the Government assumed control of the soybean processing industry as a war-time measure, not one had proved itself successful by independently operating for any extended period in direct competition with larger mills.

It is true that freight savings allow a greater margin for processing expensesin the 5-ton or 10-ton plant which operates only in the local market, as compared with a larger mill which ships raw materials and products considerable distances. It is also true that unavoidable items of overhead expense in the small mill greatly increase the processing cost, per bushel, over that which would be obtained if larger equipment were used.

Expellers and screw presses designed for soybeans are not made commercially with capacities less than 15 or 20 tons per day, and this size has proved quite satisfactory under some conditions. Most efforts to develop 5-ton and 10-ton plants have consequently been devoted to solvent extraction, and the principal difficulty encountered is that the only cheap solvents available are similar to gasoline and are hazardous to use. In large extraction plants extreme measures are taken to minimize explosion hazards, and it requires technically trained personnel to maintain the requisite standards of safety. The extremely small mill can hardly afford to retain a staff with the training necessary to avoid accidents and to maintain the operating conditions in equipment as complex as solvent extractors.

During the past ten or more years, the Ford Motor Company has experimented with small-scale soybean processing and has operated two small plants to demonstrate the method developed by their research staff. However, in spite of considerable publicity and a number of attempts of others to use such a process on a small scale, the Ford installations are still the only ones of their type in operation. Moreover, the Ford Motor Company has subsequently built and is operating a considerably larger soybean mill which has been used, at least until the United States became involved in World War II for supplying oil for varnishes and other materials entering into the manufacture of the Ford automobile.

A final answer to this question, i.e. the feasibility of using extremely small solvent units, may be forthcoming as the result of the recent placing on the market of 5-ton and 10-ton extractors designed for use of a fireproof solvent, trichloroethylene. This solvent is about 5 to 6 times more expensive than the hexane used in larger solvent mills, and it has never before been employed on a large scale by the soybean industry. One manufacturer who developed such apparatus has recently installed one rated at 10 tons of soybeans per day, and at least 3 others are being built by other firms. No estimates are yet available on the unit cost of operation, as compared with the one-expeller mill, but the results obtained in these initial installations will be watched with great interest by those who have studied the question of milling soybeans on a small scale.

In considering the economic aspects of a soybean processing business -- for example, one that is still in the blue-print stage -- one must realize that small-scale and seasonal operations can hardly be avoided in many marginal areas where the volume of soybeans available is limited. The result of part time operations is obviously higher unit operating costs, but these are frequently compensated for by favorable marketing conditions and other factors. The former require further explanation, but as an example of the latter there might be cited the instances in which certain mills, located somewhat distantly from the main producing areas, have crushed soybeans part of the year and linseed or other oilseeds the remainder of the season.

Milling-in-transit-privilege

In order to understand fully the factors which must be considered when evaluating the optimum size and location of a soybean mill, it is necessary to make a distinction between so-called "local" and "transit" processing operations. Some mills confine their activities largely to one or the other type of operation, and many carry on both.

Local operations are those in which the beans are purchased from growers in the immediate vicinity and the meal is sold to local feeders. There are usually no freight charges on the soybeans or the finished meal or, in any case, these charges are small.

Transit milling is based upon the "milling-in-transit" privileges extended to processors in cases where the raw materials, shipped from some distant point, are unloaded at the plant, milled, and the resulting meal shipped to some ultimate destination further along the same route used to bring the raw material to the mill. In other words, the plant is located on the transportation route that might normally be employed to ship the beans from the point of origin to the ultimate destination of the meal. Under these conditions, the soybeans are milled in transit, that is, the oil is removed during a brief stopover at the mills. This, obviously, represents a saving in freight over milling operations in which the outbound products move to market on a new freight billing independent of the freight billing of the inbound raw material.

Railroads operate under a very complex system of milling-in-transit schedules, and all soybean mills engaging in transit milling require the services of a traffic expert to assist the soybean buyer and meal salesman in arranging purchases and sales to take advantage of available "through billing" regulations.

Some localities are much more advantageously situated than others with respect to transit rates between soybean producing areas and the meal markets. For example, Decatur, Illinois, is in a particularly strategic location, with respect to soybeans and soybean oilmeal, and it is for this reason that Decatur has by far the largest concentration of soybean processing facilities in the United States and that all sales of soybean products are normally made on an f.o.b. Decatur basis.

Because of the centralization of the soybean industry in Decatur and the consequently large volume of transit movement to and from that city, the prices of soybeans from more distant sections have, in years past, been determined largely by the transit freight rates required in order to deliver the raw material to Decatur at the market prices being paid there. Similarly, meal prices were generally determined by the transit freight rates that must be paid in order to ship meal from Decatur to destination points. In many cases, soybean prices were computed on the basis of the Chicago price less applicable freight, but meal prices were practically always the prevailing Decatur quotation plus freight.

Under the preceding conditions, it is apparent that, although a very small mill or one doing a seasonable business could hardly hope to survive if located near Decatur, those small plants situated in more remote areas enjoyed freight rate advantages which largely offset their higher operating cost. It is also obvious that the mills located some distance from Decatur could ordinarily realize a greater processing margin on that portion of their crush conducted on entirely local soybeans, as compared with that portion conducted on a transit basis. These factors require very careful consideration by anyone contemplating embarking on a soybean processing venture.

There is at least one other way in which transit rates sometimes benefit processors located in certain areas distant from the soybean belt. Whether or not "through billing" is available on the soybeans milled, shipment of the oil takes a considerably higher freight rate than that applicable to the beans and meal. It is therefore frequently an advantage to be located near the oil markets so that a substantial saving can be made in the cost of transporting the oil.

At the present time (1944-45) the freight advantages, formerly accruing in many outlying areas by virtue of the industry's centralization in Decatur, are more or less in abeyance because fairly uniform soybean and soybean oilmeal prices have been established as part of the war-time soybean program. It would be expected, nevertheless, that the practice of applying freight discounts and premiums, based on Decatur, would re-establish itself when war-time marketing restrictions are relaxed. Many new mills have been constructed since the government assumed control of the industry, however, and a considerable portion of the Iowa crop that was formerly shipped to Decatur for milling in transit may be crushed in these districts in the future. It is therefore hazardous to make any prediction regarding the exact role which the "Decatur basis" of determining prices will play in the post-war soybean industry.

Other economic factors

Another practice of the soybean industry, and one that needs little explanation, is that of hedging all purchases and sales. Processors buy most of their beans and sell most of their oil and meal for future delivery, and contracts are generally negotiated in accordance with trading rules adopted by the National Soybean Processors Association, 3818 Board of Trade Building, Chicago 4, Illinois. As in all agricultural processing industries, gambling on the markets tempts disaster. It is the usual custom to sell oil and meal corresponding to every car of beans purchased, or vice versa, at prevailing prices. Operating on this basis, the processor knows exactly what processing margin he will have on every bushel he processes. Obviously, if prevailing future prices for soybeans, oilmeal, and oil do not afford a processing margin commensurate with his expected yields and operating costs, a processor stays out of the market and awaits a price change that will enable him to do business at a profit. It is sometimes the case, however, that on account of overhead costs, an operator considers it preferable to run at a slight loss rather than to shut down his plant.

The preceding are only a few of the many factors that require thorough investigation in connection with choice of size and location of a soybean processing plant, but they are among the most important ones. The proximity of other mills which would compete for raw materials and for meal markets is likewise a vital consideration.

A word of caution here might be in order for those who contemplate soybean processing as a prospective new business venture but who have not had oil milling experience. Oilseed processing, particularly the operation of expellers, screw presses, and solvent extractors, is a highly technical field which requires the services of well-trained and experienced operators. No fixed rules can be given for conducting many steps in the processes, and it is necessary to rely entirely upon the operator's judgment, based on experience, in order to maintain proper conditions to yield marketable products with a minimum of conversion cost. The services of a reliable firm of consulting engineers with a background of oil milling experience would be an excellent investment for anyone not thoroughly familiar with the field who expects to engage in any type of soybean processing.

Location and Capacity of Existing Plants

The soybean processing industry consists, for the most part, of mills which crush nothing but soybeans and of a very few which crush soybeans most of the time but not exclusively. In addition, there are a large number of cottonseed, linseed, and other oilseed mills which handle soybeans only a small part of their operating time or which have been temporarily converted to soybean crushing to meet wartime requirements. In discussing the development and present economic position of the soybean industry, it is necessary to neglect or to treat as a small separate group the temporary and part time soybean mills, as their operations are ordinarily quite variable.

At the present time (May 1945) the total crushing capacity of the soybean industry, excluding temporary and part time mills, but including current construction, is estimated to be 547,518 bushels per day, or 189,441,000 bushels per 346-day year. Of this, 66.8 percent use expellers and screw presses, 31.4 percent use solvent extraction equipment, and 1.8 percent use hydraulic presses. Table 18 summarizes the soybean processing industry in more detail. Table 19 gives the estimated present (May 1945) capacities of the nine largest operators in the business.

Soybean processing is centralized in the North Central states, with a certain minor proportion distributed in marginal producing areas, and, in some cases, in locations rather remote from the soybean belt. The estimated distribution, by areas, is given in Table 20.

The perennial question of whether an agricultural processing industry should become centralized in a relatively few large plants or whether it should develop as a large number of community mills, each serving mainly their local producing areas, has been argued at great length by those responsible for the soybean industry's development. The linseed crushing industry is an example of the former type of operation, and the cottonseed industry exemplifies the latter extreme. In the case of the soybean industry, the major part of the crushing capacity is in the hands of a relatively few operators, but by no means to the exclusion of small mills.

Table 18.- Summary of soybean processing facilities and operation status, excluding mills crushing soybeans temporarily or less than half their operating time. - May 1945

Type of mill and status of operation	Soybean capacity	Proportion of U. S. total capacity	Soybean capacity	Proportion of U. S. total capacity
	Bu./day	Percent	Bu./day	Percent
Type of equipment used				
Anderson expellers, all types (356 presses)			228,690	41.8
Anderson super-duo expellers	160,500	29.3		
Anderson duo expellers	50,540	9.2		
Anderson RB expellers	15,100	2.8		
Anderson No. 1 expellers	2,550	0.5		
French screw presses (174 presses)			124,010	22.7
Unclassified expellers and screw presses (16 presses)			12,800	2.3
Solvent extraction plants (36)			172,018	31.4
Hydraulic press equipment			10,000	1.8
Total of all types			547,518	100.0
Operation status				
Expellers and screw presses			365,500	66.8
Now operating	326,700	59.7		
Under construction	38,800	7.1		
Solvent extraction plants			172,018	31.4
Now operating	119,358	21.8		
Under construction	52,660	9.6		
Hydraulic press equipment			10,000	1.8
Now operating	10,000	1.8		
Under construction	None			
Total now operating	456,058	83.3		
Total under construction	91,460	16.7		
Grand total			547,518	100.0

Table 19.- Estimated soybean processing capacities of nine largest operators

Processor identification	Soybean capacity		Proportion of U. S. total capacity
	Bu./day	Bu./yr.[1]	Percent
Processor A	59,500	20,587,000	10.9
Processor B	58,500	20,241,000	10.7
Processor C	50,635	17,519,710	9.2
Processor D	49,000	16,954,000	8.9
Processor E	28,400	9,826,400	5.2
Processor F	19,100	6,608,600	3.5
Processor G	17,000	5,882,000	3.1
Processor H	16,300	5,639,800	3.0
Processor I	12,650	4,376,900	2.3
Total, 9 largest operators	311,085	107,635,410	56.8

1/ Basis 346 operating days per year.

Table 20.- Capacity of soybean mills in specified areas, excluding mills crushing soybeans temporarily or less than half their operating time

Area	No. of mills	Soybean capacity	Proportion of U. S. total capacity
		Bu./day	Percent
Illinois	33	193,215	35.3
Iowa	36	107,880	19.7
Ohio	17	63,630	11.6
Indiana	16	56,723	10.4
Missouri	7	18,700	3.4
Kentucky, Tennessee, Arkansas	8	21,050	3.8
Kansas, Nebraska	14	25,630	4.7
Wisconsin, Minnesota, North Dakota Michigan, South Dakota	17	29,490	5.4
New York, Pennsylvania, Virginia California, Colorado, Delaware	12	31,200	5.7
Total	160	547,518	100.0

UTILIZATION OF SOYBEAN OIL

The diversity of uses to which the soybean and its various products are put are shown in table 21 prepared by Mr. W. J. Morse of the United States Department of Agriculture. Although it is well-known that there has been a rapid increase in the industrial use of soybean oil, the extent of this increase and its effect upon the consumption of other industrial oils may not be clear. Since soybean oil has enjoyed its rise to prominence mainly because of its acceptance as an edible oil, its increased consumption has occurred at the expense of other food fats, particularly cottonseed oil and lard. In the few years preceding the present war, a serious oversupply of food fats and oils in this country resulted in drastically depressed prices, and soybean oil was a leading contributor to this surplus. Analysis of the effect of the introduction of soybean oil into the established fats and oils economy, and the extent of the upheaval caused by this "intruder", is the purpose of this section.

The increase in the quantity of soybeans crushed and the growing proportion of the quantity crushed to the quantity produced for the period 1924 to 1943 are shown in table 13, page 30. As production increased from 5 million bushels in 1924 to 187 million bushels in 1942, crushings ranged from 307,000 bushels in 1924 (Oct. 1 - Sept. 30) to 77,000,000 bushels in 1941 and to 133 millions in 1942. Similarly the proportion of soybeans crushed increased from 6.2 percent of the 1924 crop to 71 percent of the 1942 crop.

The increasing importance of soybean oil in our economy is brought into sharp relief by examining table 22.* Of the total factory consumption of vegetable oils, amounting to 3.1 billion pounds in 1935, only 91 million pounds, or approximately 3 percent of it, was soybean oil, whereas, in 1944, factory consumption of soybean oil amounted to 1,036 million pounds, a quantity representing approximately 30 percent of the 3.5 billion pounds of all vegetable oils consumed as a raw material by industry in that year. With the exception of 1937 the quantity of soybean oil consumed annually in industry has shown an uninterrupted increase since 1935. Moreover, its relative importance in the vegetable oil field has advanced each year except for slight set-backs in 1937 and 1941. This indicates that, although the expansion in the factory consumption of soybean oil has been given impetus since 1939 by the difficulty encountered in importing certain oils, the enormous expansion in use of soybean oil has been due in large measure to its versatility in utilization, to favorable price relationship, to tariff protection** and to the aggressiveness of agricultural leaders in encouraging soybean culture and of processors in urging the acceptance of soybean products in industry and elsewhere.

---

* Table 22A compares factory consumption and total apparent domestic disappearance. The discrepancies between the totals for factory consumption in tables 22 and 22A may be ascribed to the use of different sources of data, and to the fact that most of the data are preliminary (see also footnote 1/ table 22).

** Soybean oil - 3-1/2 cents per pound but not less than 45 per centum ad valorem
Soybeans - 2 cents per pound.
Soybean oil-cake and soybean oil-cake meal - 1/5 cent per pound.
Soybeans, prepared or preserved in any manner - 6 cents per pound.

Table 21. Soybean utilization

- **SOYBEAN**
  - **Plant**
    - Forage / Green Manure / Pasture
      - Ensilage
      - Fuel
      - Furfural
      - Hay
      - Soilage
  - **Bean**
    - Defatted meal
      - Emulsifier
      - Core binder
      - Feeds
        - Cattle
        - Dogs
        - Fish
        - Hogs
        - Poultry
        - Rabbits
        - Sheep
      - Fertilizer
      - Glue
      - Human food
        - Grits
        - Beer brewing
        - Flour-see whole beans
        - Seasoning powders
        - Soy sauce
        - Vegetable milk
      - Plastics
      - Industrial protein
        - Paints
        - Paper size
        - Textile dressing
        - Waterproofing
    - Oil
      - Candles
      - Celluloid
      - Core oil
      - Disinfectant
      - Electrical insulation
      - Enamels
      - Food products
        - Dip coatings
        - Margarine
        - Cooking oils
        - Shortening
        - Salad oils
        - Medicinal oil
      - Fuel
      - Glycerin
      - Insecticides
      - Lecithin
        - Cocoa
        - Emulsifier
        - Margarine
        - Medicines
        - Textile dyeing
        - Candy
        - Chocolate
        - Gasoline stabilizer
      - Lighting
      - Linoleum
      - Lubricant
      - Oilcloth
      - Paints
      - Printing ink
      - Rubber substitutes
      - Soaps
        - Hard
        - Liquid
        - Soft
      - Synthetic resins
      - Varnishes
      - Waterproof for cement
      - Waterproof goods
    - Green Bean
      - Canned
      - Frosted
      - Green vegetable
      - Salad

(Continued on next page)

Table 21 Cont'd - Soybean Utilization

- Whole bean
  - Baked
  - Boiled
  - Breakfast foods
  - Feeds
    - Cattle
    - Hogs
    - Poultry
    - Sheep
  - Flour
    - Baked products
    - Breakfast foods
    - Candies
    - Chocolate
    - Diabetic foods
    - Health drinks
    - Ice cream cones
    - Ice cream powder
    - Infant foods
    - Macaroni products
    - Meat products - filler
  - Grits
  - Roasted
    - Candied
    - Coffee substitute
    - Salted
  - Soy sauce
  - Sprouts
  - Vegetable milk
    - Casein
    - Condensed
    - Curd
      - Canned
      - Dried
      - Fermented
      - Fresh
      - Smoked
    - Foods
    - Powder

Table 22. - Factory consumption of various primary vegetable oils and total animal fat; 1935-1944
(See also Table 22-A)

Fats and oils	Factory consumption of specified oils during -									
	1935	1936	1937	1938	1939	1940	1941	1942	1943 1/	1944 1/
	Million of pounds									
Soybean	91.2	184.6	178.5	237.4	369.8	431.6	463.7	617.4	960.3	1,035.8
Linseed	291.7	305.3	375.2	298.5	345.0	386.2	539.4	568.6	536.2	571.4
Cottonseed	1,339.7	1,302.8	1,686.8	1,540.0	1,321.2	1,280.0	1,443.6	1,280.9	1,327.5	1,073.0
Peanut	109.4	103.7	67.5	62.5	67.1	39.5	114.3	62.0	86.6	104.0
Corn	56.1	72.1	83.8	72.8	84.1	88.4	84.3	129.5	120.4	69.5
Coconut	582.1	602.3	425.9	555.0	529.2	528.2	638.0	181.2	190.8	199.7
Palm	251.4	301.4	331.1	253.2	271.0	157.2	278.5	122.9	62.3	56.3
Tung	114.3	107.9	120.4	87.4	90.7	59.1	54.0	11.9	12.0	10.1
Perilla	41.6	80.0	42.5	32.6	42.5	18.6	7.0	2.6	1.7	0.5
Rapeseed	35.8	50.9	14.3	5.3	6.6	8.8	14.5	14.1	19.7	20.1
Sesame	54.3	55.3	37.7	7.6	2.3	1.3	0.9	0.3	0.9	1.0
Others 2/	170.0	196.2	274.2	167.1	179.5	166.5	178.7	188.5	138.5	351.5
Total vegetable	3,137.6	3,362.5	3,637.9	3,319.4	3,309.0	3,165.4	3,816.9	3,179.9	3,456.9	3,492.9
Total Animal	1,352.1	1,412.7	1,326.0	1,319.7	1,494.0	1,572.5	2,046.3	2,267.0	2,272.7	2,543.8
Grand total	4,489.7	4,775.2	4,963.9	4,639.1	4,803.0	4,737.9	5,863.2	5,447.1	5,729.6	6,036.7

1/ These data are only approximate. Changes in methods of reporting factory consumption occurred both in 1942 and 1944, causing difficulties in summarizing these data in a comparable form with earlier years. They are as nearly comparable as is possible to obtain.
2/ Includes olive, palm-kernel, castor, babassu, and other vegetable oils.

Compiled from Bureau of Census Statistics.

Table 22-A.- Factory consumption and total apparent domestic disappearance of various primary vegetable oils and animal fats, 1940-1943

Fats and oils	Factory consumption				Total apparent disappearance 1/			
	1940	1941	1942	1943 2/	1940	1941	1942	1943 2/
	Millions of pounds				Millions of pounds			
Soybean	431.6	463.7	642.1	1,055.1	499.1	555.9	718.3	1,134.7
Linseed	386.2	538.4	568.6	536.2	550.1	316.3	831.6	773.5
Cottonseed	1,230.0	1,443.5	1,322.1	1,420.6	1,377.6	1,565.9	1,400.9	1,314.2
Peanut	39.5	114.3	66.8	95.0	61.3	145.[illegible]	93.9	124.1
Corn	88.4	84.3	138.5	137.0	172.0	174.1	233.6	239.3
Coconut	582.2	638.0	182.9	200.4	597.8	726.5	201.6	195.6
Palm	157.2	278.5	122.9	62.3	130.6	291.6	129.4	65.3
Tung	59.1	54.0	11.8	12.0	66.9	63.5	14.7	8.2
Perilla	13.6	7.0	2.6	1.7	19.5	8.6	3.7	2.0
Rapeseed	8.3	14.5	14.2	19.7	12.9	3.8	19.1	16.1
Sesame	1.3	0.9	0.3	0.9	5.2	5.5	0.8	2.4
Babassu	55.5	39.0	22.1	26.1	60.2	41.3	34.0	23.7
Castor	54.0	39.9	90.6	64.4	90.3	157.5	154.6	93.6
Olive, edible	4.8	2.5	1.4	1.6	52.8	22.1	15.7	16.7
Olive, edible	6.1	2.7	0.7	0.6	5.7	2.6	0.4	1.7
Olive, foots	15.9	10.6	5.1	5.1	17.3	11.4	4.4	4.6
Palm-kernel	6.8	10.4	1.9	1.7	11.6	6.8	2.1	1.2
Other vegetable	23.4	23.8	43.2	13.2	--	--	--	--
Total vegetable	3,219.4	3,317.0	3,242.8	3,653.6	3,321.4	4,609.3	3,888.8	4,621.9
Total animal	1,572.6	2,046.4	2,267.3	2,272.0	3,682.4	4,130.0	4,219.7	4,335.0

1/ Total apparent domestic disappearance.
2/ Preliminary.

Source: Agricultural Statistics for 1943 and 1944.

Table 22 shows also the factory consumption of the various other vegetable oils and their relative importance for the years 1935 to 1944. It will be noted that along with soybean oil, the relative positions of linseed and corn oils have likewise appreciated, although not so greatly as soybean oil.

Previous to 1935 soybean oil in the United States was used principally in paints and varnishes. Since that date, however, 70 to 93 percent of annual factory consumption of soybean oil has been in the food industries, 2 to 20 percent in the drying oil industry, 1 to 6 percent in the soap industry, and 1 to 5 percent in miscellaneous uses. Loss, including "foots," has accounted for 4 to 9 percent.(see table 23).

The quantity and the relative importance of soybean oil consumed in industry, by classes of products, as compared to all vegetable oils, are shown in table 24. This table reveals an increased use of soybean oil in all products using oils as a basic constituent. The greatest increases shown were in food uses, but substantial increases also were shown in the quantity consumed in the drying oil industries and for miscellaneous uses, except during the War period 1942-44.

In order to examine in detail the utilization and economic status of soybean oil and to determine how its use has affected the consumption of other vegetable oils, it is perhaps best to consider separately each class of product in which oils are a basic constituent. These classes of products, as reported by the Bureau of Census and as they appear in tables 23 and 24 are: Shortening, margarine, other edible products, soap, paint and varnishes, linoleum and oil cloth, printing inks, miscellaneous products, and loss (including "foots"). Each of these products is hereinafter considered individually and the situation as regards soybean oil within each class of product since 1935 is considered, except that no special reference will be made to the effect of World War II on comsumption and importation of vegetable oils.

Shortening

The shortening industry is the largest individual consumer of vegetable oils, consuming for the period 1935-41 an average of about 1-1/3 billion pounds annually (table 25). Cottonseed oil is used to the largest extent for this purpose, contributing on the average, about 72 percent of this amount (table 26). The quantity of soybean oil used in shortening increased from 52.5 million pounds in 1935 to approximately 620 million pounds in 1944 (table 24), or an increase from 4 to 52 in the percentage of total uses during the period. In shortenings, soybean oil is used either alone or blended with other fats and oils. Since shortenings compete directly with lard and constitute the largest single usage of soybean oil, the price of soybean oil has fluctuated more or less in

Table 23. - The proportion of the annual factory consumption of soybean oil by classes of products, 1935-1944

Year	Proportion of factory consumption of soybean oil for -											Total
	Food uses					Drying industries						
	Shortening	Margarine	Other 1/ edible products	Total	Soap	Paint and varnish	Linoleum and oilcloth	Printing inks	Total	Miscellaneous products 2/	Loss 3/ (including oils in foots)	
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
1935	57.5	1.9	10.3	69.7	2.8	14.3	5.3	0.1	19.7	1.8	6.0	100.0
1936	61.7	7.7	11.7	81.1	2.7	7.8	1.6	.0	9.4	1.9	4.9	100.0
1937	50.9	17.8	8.7	77.4	5.8	9.0	.5	.0	9.5	1.7	5.6	100.0
1938	57.8	16.8	4.8	79.4	4.6	6.4	1.5	.0	7.9	2.2	5.9	100.0
1939	54.5	19.2	8.8	82.5	3.0	5.9	1.7	.0	7.6	2.5	4.4	100.0
1940	49.2	20.2	9.3	78.7	4.1	6.9	1.7	.0	8.6	3.8	4.8	100.0
1941	46.6	16.3	10.3	73.2	5.3	9.0	1.6	.1	10.7	5.1	5.7	100.0
1942 4/	54.3	21.6	9.8	85.7	5.1	4.1	5/	5/	4.1	1.3	6/ 8.9	100.0
1943 4/	59.2	20.6	13.0	92.8	1.5	1.9	5/	5/	1.9	1.8	6/ 3.5	100.0
1944 4/	59.9	18.5	12.0	90.4	4/	1.8	5/	5/	1.3	3.0	6/ 4.8	100.0

1/ Salad oils.
2/ Includes cutting fluid, core oils, candles, lamp oil, livestock fly spray, rubber substitutes, sticker for lead arsenate spray, waterproofing cement, etc.
3/ Mostly foots, used chiefly in soap
4/ These data are only approximate. Changes in methods of reporting factory consumption occurred both in 1942 and 1944, causing difficulties in summarizing these data in a comparable form with earlier years. They are as nearly comparable as is possible to obtain.
5/ Less than .5 of 1%.
6/ Residual figure.

Source: Compiled from Bureau of the Census Reports.

Table 24. - Factory consumption of soybean oil by classes of products: Quantity consumed, and percentage that soybean oil is of total vegetable oils.

Year	Shortening	Margarine	Other 1/ edible products	Soap	Paint and varnish	Linoleum and oilcloth	Printing inks	Miscellaneous 2/	Loss 3/ (including foots)
Quantity consumed - million pounds									
1935	52.5	1.7	9.4	2.5	13.0	4.8	0.1	1.7	5.5
1936	113.9	14.3	21.6	5.0	14.5	2.9	0.1	3.4	9.0
1937	90.8	31.8	15.6	10.3	16.1	0.9	0.1	3.0	9.9
1938	137.1	39.9	11.3	10.9	15.2	3.6	0.1	5.3	14.0
1939	201.6	70.8	32.3	11.2	21.7	6.4	0.1	9.3	16.3
1940	212.3	87.1	40.0	17.6	29.8	7.3	0.1	16.5	20.9
1941	216.0	75.6	48.0	24.7	41.6	7.7	0.3	23.4	26.4
1942 4/	335.5	133.3	60.8	31.4	25.3	0.3	0.1	7.8	16.5
1943 4/	568.4	198.0	124.6	14.0	18.4	0.2	0.04	17.0	---
1944 4/	620.3	191.6	124.4	3.3	19.1	0.05	0.02	30.7	---
Percentage that soybean oil is of total vegetable oils									
1935	3.8	0.6	3.0	0.6	3.5	7.3	0.6	2.0	2.6
1936	8.1	4.8	6.1	1.1	3.6	3.4	0.5	3.2	4.4
1937	6.1	10.3	3.9	1.8	3.7	1.1	0.4	2.6	4.8
1938	9.9	13.6	3.1	2.1	4.4	5.1	0.5	6.4	6.0
1939	15.6	31.4	7.8	1.9	5.5	7.1	0.5	8.4	9.4
1940	19.1	37.4	8.6	3.1	7.4	7.5	0.5	13.4	14.4
1941	16.7	28.5	9.3	3.6	7.9	6.3	1.0	13.0	14.3
1942 4/	29.7	43.3	10.5	11.7	5.2	0.3	0.6	5/	5/
1943 4/	46.9	42.6	16.5	6.1	4.4	0.3	0.2	5/	5/
1944 4/	52.4	42.5	20.6	1.7	3.8	0.1	0.1	5/	5/

1/ Mayonnaise, salad dressings, cooking oils, etc.
2/ Includes cutting fluid, core oils, candles, lamp oil, livestock fly spray, rubber substitutes, sticker for lead arsenate spray, waterproofing cement, et cetera.
3/ Mostly foots, used chiefly in soap.
4/ These data are only approximate. Changes in methods of reporting factory consumption occurred both in 1942 and 1944, causing difficulties in summarizing these data in a comparable form with earlier years. They are as nearly comparable as is possible to obtain.
5/ Residual items - not strictly comparable.

Source: Compiled from Bureau of Census Reports.

Table 25. - Factory consumption of primary vegetable oils by classes of products: 1935 to 1944

Use	1935	1936	1937	1938	1939	1940	1941	1942 1/	1943 1/	1944 1/
					Million pounds					
Shortening	1,374.6	1,414.4	1,486.4	1,390.5	1,295.9	1,111.3	1,295.5	1,130.7	1,210.7	1,182.7
Margarine	282.4	298.6	307.5	292.8	225.4	233.1	265.2	308.2	464.8	450.7
Other edible products	311.0	356.5	403.9	363.4	413.0	463.0	516.2	578.8	754.8	604.0
Soap	411.4	474.5	578.4	523.2	580.5	569.4	694.5	269.4	229.2	197.3
Paint and varnish	375.4	405.6	430.9	342.2	397.9	403.6	529.6	490.0	419.1	498.0
Linoleum and oilcloth	67.0	85.1	84.6	70.3	90.3	96.8	122.2	108.0	73.0	81.5
Printing inks	17.3	19.5	25.4	21.2	22.2	20.6	28.6	16.8	22.0	29.1
Miscellaneous	86.9	104.9	116.1	82.6	111.2	122.7	179.9	191.0	204.5	319.3
Loss (Including oil in foots)	211.6	203.4	204.7	233.2	172.6	144.9	185.2	87.0	---	---
Total	3,137.6	3,362.5	3,637.9	3,319.4	3,309.0	3,165.4	3,816.9	3,179.9	3,456.9	3,492.9

1/ These data are only approximate. Changes in methods of reporting factory consumption occurred both in 1942 and 1944, causing difficulties in summarizing these data in a comparable form with earlier years. They are as nearly comparable as is possible to obtain.

Source: Compiled from U. S. Bureau of Census Statistics.

Table 26. - Percent of specified oils used in shortenings in relation to the total factory consumption of vegetable oils in 1935-44.

Oil	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Cottonseed	72.2	65.0	78.2	75.6	69.8	74.1	68.6	61.3	47.3	41.4
Soybean	3.8	8.1	6.1	9.9	15.6	19.1	16.7	29.7	46.9	52.4
Peanut	6.6	6.3	3.9	3.8	4.0	2.0	6.3	3.3	4.2	5.2
Coconut	3.2	2.7	.8	1.9	1.6	1.6	1.7	.4	1/	1/
Palm	8.5	11.9	8.3	8.3	8.7	3.0	6.7	2.6	1/	[illegible]
Other	5.7	6.0	2.7	.5	.3	.2	.0	2.7	1.6	11.0
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

1/ Less than .5 of 1 percent.

Source: Computed from reports of the Bureau of Census.

accordance with that of lard during recent years. In table 26 are presented data showing the relative importance of the various oils consumed in the shortening industry for the period 1935-1944.

Margarine

During the period 1935-41 the annual factory consumption of vegetable oils in the margarine industry averaged about 270 million pounds, or 8 percent of all vegetable oils. For the period 1942-44 factory consumption has averaged 408 million pounds. Since 1935 significant shifts have occurred in the proportion of various oils which are used for this purpose. In 1935 coconut oil made up 61.7 percent (table 27) of all vegetable oils used in margarine, soybean oil contributed 0.6 percent, and cottonseed oil 35.2 percent. In 1941 the percent of margarine made from coconut oil declined to 11.2 percent, while the consumption of soybean oil for this purpose rose to 28.5 percent, and of cottonseed oil to 56.6 percent of the total. By 1944 the use of coconut oil had ceased while soybean oil had increased to almost 50 percent. These shifts have been continuous (i.e. accumulative from year to year) from 1935 to 1941 and so apparently were not the result of an abrupt shutting off of coconut imports. In table 27 data are presented which show the relative importance of various vegetable oils in the margarine industry over the 1935-44 period.

Other Edible Products

The factory consumption of vegetable oils for "other edible products" (mayonnaise, salad dressings, cooking oils, etc.) increased from approximately 10 percent of all uses in 1935 to approximately 14 percent in 1941 and to 17 percent in 1944 (table 25). In these uses cottonseed oil is by far the heaviest contributor, accounting for from 45 percent in 1935 to 60 percent in 1944 (table 28). The proportion accounted for by soybean oil in the manufacture of these products, increased from 3 percent to 25 percent during the same period. Coconut oil and sesame oil have been the oils which chiefly have decreased. These shifts are shown in table 28.

Soap

The total and relative amounts of vegetable oils used in the manufacture of soap have been increasing (table 25). The quantity used increased from a little over 400 million pounds in 1935 to almost 700 million in 1941 but decreased thereafter to about 200 million pounds in 1944. In 1935, 2-1/2 million pounds of soybean oil was used in the manufacture of soap, whereas in 1941 this amount increased ten-fold, or to 25 million pounds. In 1944 the amount decreased to 3 million pounds (see table 24).

Table 27. - Percent of specified oils used in margarine in relation to the total factory consumption of vegetable oils for margarine, 1935-44.

Oil	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Coconut	61.7	50.4	24.0	30.6	17.1	9.4	11.2	1.1	---	---
Soybean	0.6	4.8	10.3	13.6	31.4	37.4	23.5	43.3	42.6	46.8
Cottonseed	35.2	36.2	56.5	48.8	43.8	49.7	56.6	54.0	54.2	47.7
Other	2.5	8.6	9.2	7.0	7.7	3.5	3.7	1.6	3.2	5.5
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: Computed from reports of the Bur. of Census.

Table 28. - Percent of specified oils used in edible products other than shortening and margarine, in relation to the total factory consumption of vegetable oils, 1935-44.

Oil	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Cottonseed	44.6	50.0	56.1	54.5	56.5	56.9	60.4	63.4	65.7	60.0
Soybean	3.0	6.1	3.9	3.1	7.8	8.6	9.3	10.5	16.5	24.9
Coconut	23.0	16.3	12.4	16.9	10.6	11.8	10.5	2.5	1/	1/
Corn	11.6	14.3	15.8	15.7	15.8	15.3	12.2	13.5	13.6	8.1
Sesame	4.7	4.7	.8	.4	.3	.2	1/	1/	1/	1/
Peanut	1.2	.7	.5	.5	2.1	2.1	3.5	2.6	3.4	4.0
Other	6.9	7.4	10.5	8.9	6.9	5.1	4.1	2.5	4.8	3.0
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

1/ Less than .5 of 1%.

Source: Compiled from reports of the Bur. of Census.

Since the total quantity of vegetable oils going into soap was increasing simultaneously during the pre-war period, the relative importance of soybean oil in soap manufacture showed only a six-fold increase, or from 0.6 to 3.6 in percent of total vegetable oils so used (table 29). There are two reasons for the relatively small proportion of soybean oil used in soap in comparison with other oils. First, because of its high content of fatty acids having 18 carbon atoms, soaps made from soybean oil do not have the free lathering properties characteristic of those containing larger proportions of palmitic, myristic, and lauric acids. Secondly, the yield of glycerine obtained in making soap from soybean oil is considerably less than when other oils containing more short chain fatty acids are used.

Coconut oil is the chief oil used in soap, and its use for this purpose has been increasing. In 1935, 56 percent of all vegetable oils going into soap was coconut, while in 1944, nearly 70 percent was of that type. During the same period the proportion of rapeseed and palm oils generally declined. Table 29 shows in detail the relative utilization of the various oils in soap manufacturing.

Paints and Varnishes

Paints and varnishes, on the average, account for approximately 12 percent of the factory consumption of vegetable oils (table 25). There is a large amount of oil, especially linseed, however, which goes into paint and varnishes by hand-mixing and is not accounted for by these figures which show only factory consumption. Linseed oil is the oil most extensively used for the production of paint and varnishes. Its factory consumption increased from 230 million pounds, or 61 percent of all oils so used, in 1935 to 374 million pounds, or 71 percent, in 1941. By 1943 the amount of linseed oil used increased to 88 percent but in 1944 decreased to 77 percent (table 30). Soybean oil used in paints and varnishes increased from 13 million pounds in 1935 to 42 million pounds in 1941 (table 24), an increase from 3.5 to 7.9 in percent of all vegetable oils used by factories for the production of paints and varnishes during this period. During the years 1942-44 the use of soy bean oil gradually decreased to 3.8 percent.

There are two general types of drying oils used in paints and varnishes. The first is exemplified by tung oil, which is normally imported from China. During recent years the supplies of this oil were curtailed through shipping difficulties incidental to the war, and a number of substitutes therefore were introduced. Most important of these is dehydrated castor oil, but Brazilian oiticica oil has also been employed extensively. These oils are particularly valued because of their fast-drying properties and the water resistance of their film.

Table 29. - Percent of specified oils used for soap, in relation to the total factory consumption of vegetable oils, 1935-44.

Oil	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Coconut	55.8	64.8	43.6	65.6	67.0	69.7	69.7	52.2	62.1	66.7
Soybean	.6	1.1	1.8	2.1	1.9	3.1	5.6	11.7	6.7	1.7
Palm	21.2	16.5	24.4	17.5	17.6	14.9	18.7	20.7	14.2	10.0
Rapeseed	1.9	1.6	.2	---	---	---	---	---	---	---
Other	20.5	16.0	30.0	14.8	13.5	12.3	8.0	15.4	17.0	21.6
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: Computed from reports of the Bur of Census.

Table 30. - Percent of specified oils uses in paints and varnishes in relation to the total factory consumption of vegetable oils, 1935-44.

Oil	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Linseed	61.3	57.5	62.0	63.3	62.1	66.9	70.6	80.0	87.6	77.3
Soybean	3.5	3.6	3.7	4.4	5.5	7.4	7.9	5.2	4.9	3.8
Tung	26.2	23.3	24.5	22.9	20.7	13.5	9.2	2.2	2.3	1.6
Perilla	7.2	13.1	7.4	6.9	7.2	3.6	1.0	1/	1/	1/
Other	1.8	2.5	2.4	2.5	4.5	8.6	11.3	12.6	5.2	17.3
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

1/ Less than .5 of 1%.

Source: Computed from reports of the Bur. of Census.

The second group of drying oils is exemplified by linseed oil, which is slower drying than tung oil and which does not yield films having the high water resistance which characterizes tung oil products. Soybean oil belongs to this class. However, its higher content of saturated and oleic acids makes it considerably inferior to linseed oil in most of its drying properties. Because of the shortage of tung oil and certain other oils of similar drying characteristics, efforts are being made to replace them with linseed and soybean oils wherever possible. In many cases, a degree of water resistance comparable to that of tung oil may be achieved by incorporating certain synthetic resins with bodied linseed and soybean oils. A more recent development in the tung oil substitute field is the isomerization of the linoleic and linolenic acids in soybean and linseed oils in order to make a product similar to tung oil. The commercial production of these materials is very small at present. The relative use of the various vegetable oils in paints and varnishes for the years 1935-44 are shown in table 30.

Linoleum and Oilcloth

From 67 to 122 million pounds (table 25), or about 2 to 3 percent of the total factory consumption of vegetable oils, went into linoleum and oilcloth during the 1935-41 period. From 1942 to 1944 it decreased from 108 million pounds to 82 million pounds. Linseed is the predominating oil in this industry, contributing 62 percent of the total factory consumption in 1935, 90 percent in 1941, and 98 percent in 1944 (table 31). Soybean oil showed no consistent trend throughout the period, varying from a high of 7.5 percent of the total in 1940 to a low of 1.1 percent in 1937. Beginning in 1942 its use has been negligible. Perilla and tung oils were, until 1940, next to linseed in importance, but since 1941 the use of these oils has been negligible. Table 31 shows the status in use of the various oils within the linoleum and oilcloth industries for the 1935-44 period.

Printing Inks

Seventeen million pounds (table 25) of vegetable oils were consumed by the printing ink industry in 1935, 82.7 percent (table 32) of this was made up of linseed oil, 11.6 percent of tung oil, 4.6 percent of perilla oil, and only 0.6 percent, or 100,000 pounds, of soybean oil. The factory consumption of vegetable oils for the production of printing inks increased to almost 29 million pounds in 1941. Soybean oil consumption for this purpose increased from 100,000 pounds to 300,000 pounds or from a position representing 0.6 percent of the total used to one representing 1.0 percent. In table 32 is shown, for the 1935-41 period, the proportionate consumption of the various oils in the production of printing inks. For the period 1942-44 linseed oil was used almost exclusively.

Table 31.- Percent of specified oils used for linoleum and oilcloth in relation to the total factory consumption of vegetable oils, 1935-44

Oil	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Linseed	62.4	58.9	80.6	78.8	75.3	87.1	90.2	97.7	99.2	98.2
Soybean	7.2	3.4	1.1	5.1	7.1	7.5	6.3	1/	1/	1/
Tung	15.5	8.3	8.5	5.8	4.2	2.2	1.6	1/	---	---
Perilla	14.3	20.8	9.6	10.0	12.0	2.5	.2	1/	---	---
Other	.6	8.6	.2	.3	1.4	.7	1.7	2.3	.8	1.8
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

1/ Less than .5 of 1%

Source: Computed from reports of Bur. of Census.

Table 32. - Percent of specified oils used in printing inks in relation to the total factory consumption of vegetable oils, 1935-44.

Oil	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Linseed	82.7	76.9	79.9	79.2	78.8	83.0	82.2	91.1	97.3	94.5
Soybean	.6	.5	.4	.5	.5	.5	1.0	.1	1/	1/
Tung	11.6	11.3	11.0	9.9	9.5	8.3	10.5	1.5	1/	1/
Perilla	4.6	9.7	7.1	8.5	8.6	5.3	2.8	1.7	0.8	1/
Other	.5	1.1	1.6	1.9	2.6	2.9	3.5	5.6	1.9	5.5
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

1/ Less than .5 of 1%.

Source: Computed from reports of the Bur. of Census.

Miscellaneous Products

Miscellaneous products, including cutting fluid, core oils, candles, lamp oil, livestock fly-spray, rubber substitutes, sticker for lead arsenate spray, waterproofing cement, etc., are a rather small, but growing, outlet for vegetable oils. In 1935 approximately 87 million pounds or 2.8 percent of the factory consumption of vegetable oils for all purposes went into these uses (table 25). In 1941, 180 million pounds were so used, a quantity representing 4.7 percent of the total of vegetable oils (comparable data are not available for the period 1942-44). Palm, linseed, and soybean oils are the largest individual contributors to these uses. Since 1935 the use of soybean oil increased from a position representing 2.0 percent to one representing 13.0 percent of the total of vegetable oils used for these purposes. Table 33 shows the percentage of total consumption of vegetable oil for miscellaneous uses contributed by each of the vegetable oils so used.

Table 33. - Percent of specified oils used in the manufacture of miscellaneous products 1/ in relation to the total factory consumption of vegetable oils, 1935-41 2/.

Oils	1935	1936	1937	1938	1939	1940	1941
	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Palm	19.7	23.3	28.7	24.1	26.7	26.3	24.3
Soybean	2.0	3.2	2.6	6.4	8.4	13.4	13.0
Linseed	4.8	5.2	14.2	10.0	9.5	10.6	15.8
Rapeseed	12.5	9.7	6.5	5.8	5.8	7.1	7.9
Coconut	4.0	3.7	5.9	4.4	3.5	3.7	4.8
Corn	4.4	3.8	3.4	4.0	1.4	1.7	1.6
Tung	3.9	3.6	4.0	3.5	2.2	.6	.2
Perilla	4.5	6.8	.9	.5	1.1	.4	.2
Other	44.2	40.7	33.8	41.3	41.4	36.2	32.2
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

1/ Includes cutting fluid, core oils, candles, lamp oil, livestock fly-spray, rubber substitutes, etc.

2/ Because of the change in reporting of factory consumption which took place in 1942, the data for miscellaneous products is not comparable for 1942-43-44.

Source: Computed from Bur. of Census Reports.

Soybean oil has been handicapped in some respects by the fact that it falls about midway between the edible and the drying oils in many of its properties. Like most naturally occurring materials, it is a mixture of chemical compounds having widely differing characteristics, and it has been found possible to separate these compounds by recently developed fractionation processes. Distillation of the free fatty acids has been practiced on a modest scale for several years to achieve this objective, and liquid-liquid extraction has more recently received attention. Methods have been developed and will undoubtedly find extensive application for separating soybean oil into two fractions, one being better for drying purposes and the other far superior for food uses than the original oil.

New Developments

Linoleic acid, which comprises 55 to 60 percent of the acids in soybean oil, is an extremely valuable starting material for the industrial manufacture of synthetic polymers because it readily combines with itself to form long-chain dibasic acids. These can be chemically altered in many ways and subsequently polymerized to form a wide variety of resinous materials having useful properties. The importance of linoleic acid in polymerization processes has not been fully appreciated in the past, but recent developments indicate a possible major expansion in the use of soybean oil as an industrial raw material.

Two of the many new products developed from soybean oil by the Northern Regional Research Laboratory are N[illegible]-pol and Norelac. The former is an elastic vulcanizable polymer, prepared from the fatty acids of the soybean oil. It is a rubber substitute which can be used for some of the things rubber is used for, or mixed with real rubber as an extender. It does not have the stretch and strength of natural rubber but is satisfactory for such uses as insulation, rubber heels, tubing, gaskets, and water-proof coatings. During the early part of 1943, five commercial concerns were producing this product at the rate of about 70 tons a month, but later its production was reduced because of a world shortage in vegetable oils, which forced the allocation of soybean oil chiefly to other uses.

Norelac is a thermoplastic material. It is useful as a heat-sealing, moisture-proofing, and laminating agent for the packaging of foods, chemicals, and other materials.

UTILIZATION OF PROTEIN FRACTION

Feed

The soybean oilmeal, or oilcake, which remains after beans are processed for oil is a high-protein product which is used principally for feeding purposes. It is highly nutritious and is relished by all kinds of livestock. Nutritional research in recent years has shown the need for maintaining in mixed feeds a much higher protein level than had formerly been thought necessary. These findings have resulted in a vigorous educational program by many of the state agricultural experiment stations, feed manufacturers, and other groups, and a marked trend toward greater consumption of protein supplements has thereby been created. It is generally claimed that even the protein level now used in the stock feeding industries is considerably below the optimum, and a continuance of the trend toward higher protein consumption therefore seems inevitable. The supply of soybean oilmeal per crop year increased from 613,000 tons in 1935 to 3,200,000 tons in 1942.

Soybean oilmeal has been found equal or superior to other commonly used protein supplements for milk and butterfat production.[11/] In the feeding of hogs, a mixture of soybean oilmeal and bone meal has been found just as effective a protein supplement as the much-used linseed meal-tankage combination.[12/] As a part of poultry rations, the National Research Council recommends as a war-time economy measure that soybean oilmeal be substituted for dried milk. In feeding soybean oilmeal, as in feeding most other protein supplements, it is important that an adequate mineral supplement be incorporated in the ration.

Food

The most important protein food product from soybeans is soy flour, the production of which has been described in a previous section. It has many uses, one of which is as a bleaching agent in bread. Apparently through enzyme action, a very small proportion of soy flour has been found effective

---

11/ W. B. Nevens. Soybean Meal as a Feed for Dairy Cattle. University of Illinois, College of Agriculture D 362 (1940).

12 W. E. Carroll. Soybean oilmeal, a Valuable Protein Supplement for Swine. University of Illinois, College of Agriculture, AH 1012 (1940).

for whitening unbleached wheat flour by destruction of certain pigments. In much higher proportions - up to 20 percent - it may be used as an addition agent to wheat flour, since it is a potent nutrient fortifying agent.

According to LeClerc and Grewe[13/], soy flour, compared to patent wheat flour, contains 15 times as much calcium, 7 times as much phosphorus, 10 times as much iron, 10 times as much thiamin, 9 times as much riboflavin, and 5 times as much niacin. It is 4 to 5 times as rich in protein and 10 times as rich in total minerals. Full-fat soy flour contains approximately 20 percent fat and 40 percent protein; the expeller or medium-fat type of flour contains about 7 percent fat and 43 percent protein; and the solvent extracted or low-fat type has approximately 1 percent oil and 50 percent protein. Starch is substantially absent in all types.

The use of soy flour in bread has several distinct advantages. It not only greatly increases the protein content, but it also contributes certain proteins that are lacking in wheat flour, thereby furnishing a much more complete or balanced protein. A certain percentage of soy flour has also been found beneficial in the manufacturing of sweet goods, doughnuts, cakes, and similar articles to improve their texture. Because of its high protein and low carbohydrate content, soy flour is extensively used in the preparation of foods for diabetics.

In the field of meat extenders, cereal and vegetable flours have been used for a considerable time, their functions being to increase the amount of product and to retain certain amounts of the meat juices that are normally lost during cooking. Soy flour and soy grits have more recently proved greatly superior in this application, for they fulfill the ordinary requirements of a binding agent for meats, such as sausage, and also contribute to the protein content of the mixture. For such purposes they are used in widely varying proportions, 10 to 15 percent of soy grits being a common mixture.

During World War II, the need for protein-containing foods both in our own diets and for lend-lease and rehabilitation use resulted in extremely large increases in the United States production of soy flour, amounting in 1944 to a production rate of nearly a billion and a half[14/] pounds. Many of the soy flour producers are organized as the Soy Flour Association, 3818 Board of Trade Building, Chicago 4, Illinois. This group conducts and sponsors educational and research work on edible soy products.

13/ LeClerc, J. A. and Grewe, Emily, "Soybread. A Bread Enriched with Minerals and Vitamins." Soybean Digest 3 (1), 8-9 (1942).

14/ Soya Food Is Here to Stay. Soybean Digest 4 (6), 19 (1944).

Oil-free soybean flakes are used in the brewing industry. The protein is also used to prepare foods such as "Tofu," or bean curd, which is indispensable in the diets of many Orientals. Various spreads, soy sauce, and similar specialties are also made from the protein fraction, both in the U. S. and in the Orient.

Soy milk is manufactured by grinding soybeans with water, separating the pulp, and concentrating the resulting protein dispersion. It is fortified with fat, calcium, vitamins, etc., to produce an excellent substitute for cow's milk. Production in the United States is small because of the abundance of cows' milk; but in the Orient, where dairying is practically non-existent, it is used quite extensively, particularly for infant feeding.

Edible soybean varieties are available both fresh and canned and in dried or green form. They provide a very palatable dish and are unique in that, despite their physical resemblance to ordinary beans, they contain a large amount of protein and fat and little or no starch. Soybean sprouts are also used to some extent in various foods, and soybeans that have been roasted and salted are marketed as a food tidbit.

The Division of Forage Crops and Diseases, Bureau of Plant Industry, Soils, and Agricultural Engineering, U. S. Department of Agriculture, has compiled a list entitled "Firms Manufacturing or Handling Soybean Food Products," which is available for distribution and which contains the names of 73 companies and 36 different types of soy food products.

Industrial

The industrial utilization of soybean meal and protein is probably still in an early stage of development. The use of soybean meal in plastic molded articles has been over-publicized in some circles. Although no statistics on the subject are available, it is known that the tonnage thus consumed is practically negligible. Like casein, soybean protein when condensed with formaldehyde, has its thermoplastic properties greatly reduced. However, its water resistance is low, and it is therefore used only in admixture with more moisture-resistant resins, principally of the phenol-formaldehyde type. Only solvent extracted meal has been found satisfactory, for any appreciable content of oil is forced out in the molding operation, to the detriment of the finished article.

The use of either soybean protein or the oil-free meal in plastic molding powders undoubtedly has considerable possibility, but their utility in this field is handicapped by the present deficiency of knowledge about certain chemical and physical aspects of the protein molecule. As now used in molding powders, soybean meal contributes in some degree to the plastic properties of the mixed resins, but its function is principally that of a filler and extender for the more expensive resin with which it is admixed.

A much more important industrial use for soybean meal is the commercial production of a purified protein fraction which is used in the paper coating and allied fields. Solvent extracted soybean flakes are leached with water to dissolve the protein, which is subsequently purified and precipitated from solution in relatively pure form. Paper sizes, adhesives, and various coatings are made from this product. An alkaline dispersion of the protein can be forced through spinerettes to make synthetic fibers, in a manner analogous to the manufacturing of rayon. However, the production of soybean fiber is still in the experimental stage.

Glues for use in the plywood industry are made from soybean meal. In this application, the presence of a certain amount of oil is not detrimental, and it is therefore possible to use expeller type soybean oilmeal. Definite figures are not available, but it is estimated that the amount of soybean oilmeal thus used amounts to between 1/2 and 1 percent of the total domestic production.

Soybean oilmeal and ground soybeans are used to some extent as fertilizer; for example, on tobacco land and lawns. Other industrial uses of the protein are of minor importance, examples being binders for core sands and spreaders for insect sprays.

SELECTED REFERENCES

American Soybean Association, The Soybean Digest. Published monthly at Hudson, Ia.

Anonymous. Harvesting, storing and marketing soybeans. Univ. of Minnesota Agr. Ext. Service, Ext. Pam. 104. 1942.

__________ Soybeans: Harvesting; storing. Univ. of Illinois Cir. 529. 1942.

__________ Soybean oil extraction with normal hexane. Chem. and Met. 48 (9), 128-131. 1941.

__________ Busy soybean processor. Grain and Feed Jour. Consol., 79, 29. 1937.

__________ Soybeans move westward. Grain and Feed Jour. Consol., 83, 251. 1939.

__________ Swift's new soybean plant at Fostoria, Ohio. Grain and Feed Jour. Consol., 85, 281, 302. 1940.

Brother, Geo. H., et al. 1940 Soybean protein: Resume and bibliography. U. S. Dept. Agr. Mimeo. ACE-62.

Burlison, W. L. The Soybean: A plant immigrant makes good. Univ. of Illinois Agr. Expt. Sta. Cir. 461. 1936. Also in Ind. Eng. Chem. 23, 772. 1936.

__________ Eleven years of soybean investigations - varieties, seeding, storage. Univ. of Illinois Agr. Expt. Sta. Bul. 462. 1940.

Cannon, C. Y., and Johnston, Floyd. Soybeans for dairy cows. Iowa State Col. of Agr. Ext. Cir. 196, Rev. 1939.

Cartter, J. L., and Hopper, T. H. Influence of variety environment and fertility level on the chemical composition of soybean seed. U. S. Dept. Agr. Tech. Bul. 787. 1942.

Decatur Herald and Review, special soybean issue, Dec. 31, 1939, Decatur, Ill.

Durkee, M. M. Soybean oil in the food industry. Ind. Eng. Chem., 28, 898-903. 1936.

Goss, W. H. Modern practice in solvent extraction. Chem. and Met. 48 (4), 80-84. 1941.

__________ Technological problems in processing soybeans. The Soybean Digest, 1 (8), 2-3; (9) 2-3; (10) 4-5. 1941.

Grove, Ernest W. Soybeans in the United States; recent trends and present economic status. U. S. Dept. Agr. Tech. Bul. 619. 1933.

Hennefrund, Helen E. and Colvin, Ester M. The soybean industry: A selected list of references on the economic aspects of the industry in the United States 1900-1938. U. S. Dept. Agr. Mimeo. Agr. Econ. Bibliog. No. 74. 1938.

Kiesselbach, T. A., and Lyness, W. E. Soybean production in Nebraska. Univ. of Nebraska Agr. Expt. Sta. Bul. 339. 1942.

Lloyd, J. W., and Burlison, W. L. Eighteen varieties of edible soybeans. Univ. of Illinois Agr. Expt. Sta. Bul. 453. 1939.

Markley, Klare S. and Goss, Warren H. Soybean chemistry and technology. Chemical Publishing Co., Brooklyn, N. Y. 1944.

Morse, W. J. Soybean hay and seed production. U. S. Dept. Agr. Farmers' Bul. 1605. 1929.

__________ Soybean utilization. U. S. Dept. Agr. Farmers' Bul. 1617. Rev. 1932.

__________ and Cartter, J. L. Soybeans: Culture and varieties. U. S. Dept. Agr. Farmers' Bul. 1520. Rev. 1939.

Piper, Chas. V. and Morse, William J. The soybean. New York, McGraw-Hill Book Company, Inc., 1923.

Poehlman, J. M. A study of the relative adaptation of certain varieties of soybeans. Univ. of Missouri Res. Bul. 255. 1937.

Prince, Ford S., et al. Soybeans in New Hampshire. New Hampshire Expt. Sta. Cir. 57. 1941.

Ramstad, Paul E. and Geddes, W. F. The respiration and storage behavior of soybeans. Univ. of Minnesota Expt. Sta. Tech. Bul. 156. 1942.

Sears, O. H. Soybeans: Their effect on soil productivity. Univ. of Illinois Agr. Expt. Sta. Bul. 456. 1939.

Sherman, W. C., and Albrecht, H. R. Edible soybeans. Alabama Polytech. Inst. Agr. Expt. Sta. Bul. 255. 1942.

Soybean Nutritional Research Council. The composition and nutritive properties of soybeans and soybean oil meal. A literature review. 1939.

Struthers, D. K. Harvesting Soybeans. Iowa State Col. Pam. 46. 1942.

United States Department of Agriculture. Handbook of Official Grain Standards of the United States.

Van Vlack, C. H. Soybean storage. Iowa State Col. 45, 1942.

Whiteman, E. F. and Keytek, E. K. Soybeans for the table. U. S. Dept. Agr. Leaflet No. 166. 1938.

Wilcox, R. H. Costs of producing soybeans and the competitive position of the crop in Illinois agriculture. Dept. of Agr. Econ. Univ. of Illinois. Mimeo. Leaflet AE-1545.

Wooley, J. C. Emergency storage for soybeans. Univ. of Missouri Agr. Expt. Sta. Cir. 240. 1942.

Woodruff, Sybil and Klaas, Helen. A study of soybean varieties with reference to their use as food. Univ. of Illinois Agr. Expt. Sta. Bul. 443. 1938.

Zahnley, J. W. Soybean Production in Kansas. Kansas State Col. Agr. Expt. Sta. Bul. 282. 1939.